ASTRONOMICAL HERITAGES

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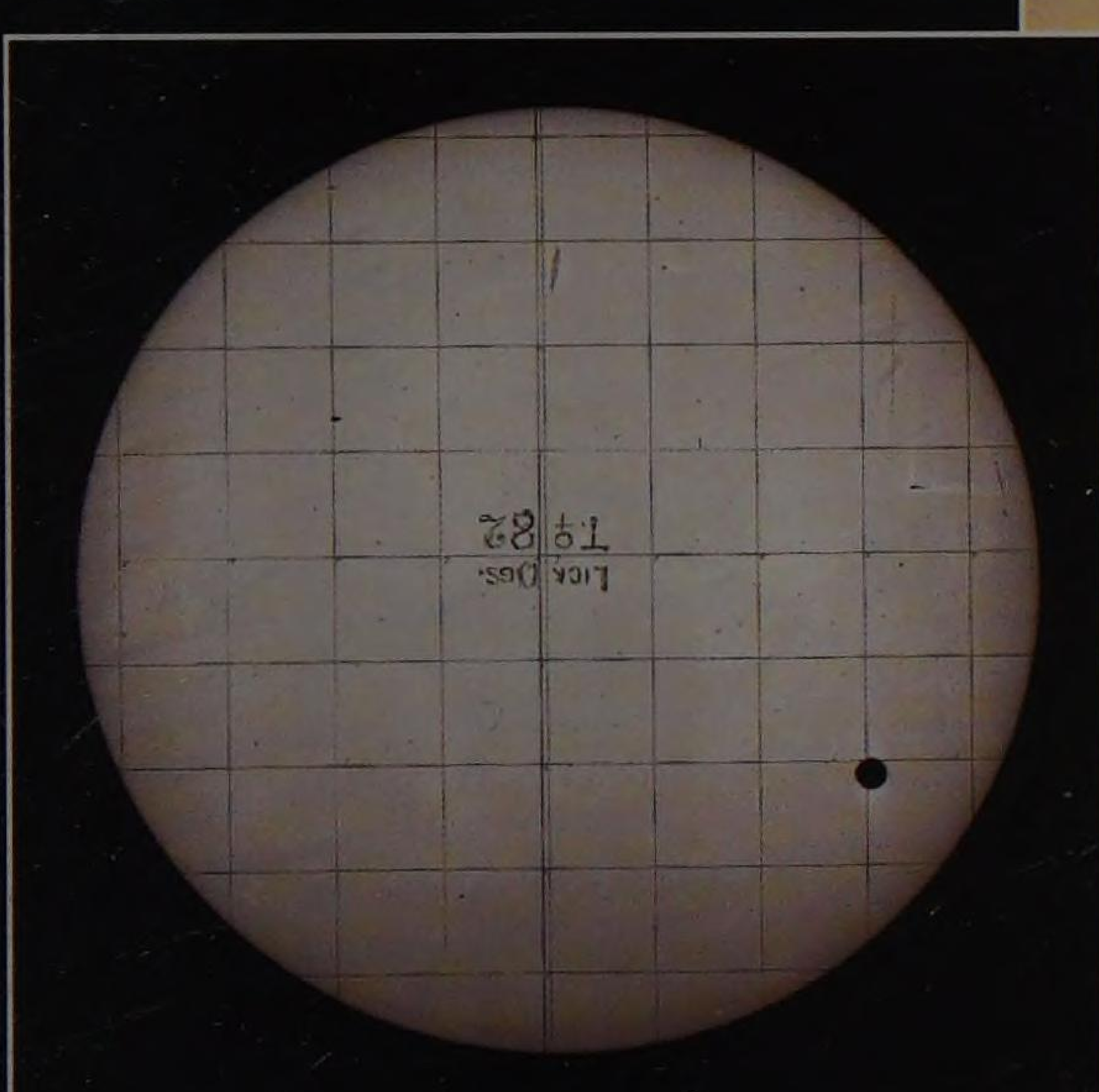
ASTRONOMICAL ARCHIVES AND HISTORIC TRANSITS OF VENUS



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あいづごよみのゆらい	会津暦之由来	一冊
あいづじんちょじゅつれき	会津人著述暦算書目録	一冊
あさだあきよししょかんな	麻田妥彰書翰并図面	一冊
あさだいのうりょうおうので	麻田伊能両翁之伝	一冊
あさだけ／りょうしょくじっ	麻田家／両食実測	一冊
あさだしょそくげっしょく	麻田氏所測月食	一冊
あさだれき	麻田暦	二冊

Christiaan Sterken and Hilmar W. Duerbeck (eds.)

ASTRONOMICAL HERITAGES

ASTRONOMICAL ARCHIVES AND HISTORIC TRANSITS OF VENUS

ASTRONOMICAL HERITAGES

ASTRONOMICAL ARCHIVES AND HISTORIC TRANSITS OF VENUS

A Selection of Papers
prepared by Working Groups
Astronomical Archives
and
Transits of Venus
of Commission 41
of the
INTERNATIONAL ASTRONOMICAL UNION

Edited by

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and
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Cover design based
on illustrations from
these Proceedings

Reprinted from
The Journal of Astronomical Data
2004, Vol. 10, 7

Published by C. Sterken
Vrije Universiteit Brussel
csterken@vub.ac.be

ISBN 9080553867
NUGI 814

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PREFACE

The International Astronomical Union (IAU) was founded in 1919 to promote the science of astronomy through international cooperation. Its Commission 41 *(History of Astronomy)* was created at the 1948 General Assembly. Currently IAU Commission 41 has five active Working Groups (WGs): the *Astronomical Archives WG, Astronomical Chronology WG, Historical Instruments WG, Historical Radio Astronomy WG* and *Transits of Venus WG.* The aim of each Working Group is to foster the exchange of information and ideas between colleagues with similar research interests, and in some instances to organise collaborative research projects.

At the 1991 General Assembly in Buenos Aires a Resolution was adopted to establish a register of the whereabouts of all extant astronomical archives of historical interest. The Archives WG was established to further the objectives of this Resolution. Two archival Resolutions proposed by Commission 41 were adopted at the 1994 General Assembly in The Hague, and a further archival Resolution was adopted at the 1997 General Assembly in Kyoto. At the 2000 General Assembly in Manchester a half-day Special Session on *Inventory and Preservation of Astronomical Archives, Records and Artifacts* was organised, and a Resolution was adopted recommending that the sites of previous transit of Venus expeditions be inventoried, marked and preserved, as well as the instrumentation and documents associated with these expeditions. The Transits of Venus WG was not only called into existence to prepare a bibliography, but "to inventory, mark and preserve the sites of previous transit of Venus expeditions, as well as instrumentation and documents associated with these expeditions".

These Proceedings contain a selection of presentations and research papers emanating from meetings of the *Astronomical Archives* and *Transits of Venus* Working Groups of Commission 41, and from presentations at the last three IAU General Assemblies. Some additional reports related to the topic of this book have also been added.

The first part of the book deals with archives, the second part with facts related to historical transits of Venus – although there is substan-

tial overlap since some archive papers deal with Transits of Venus as well.

The compilation deals with many wonderful and even rare sources of information, such as official documents and reports, private letters, astronomical instruments and telescopes, national inventories, photographic plates, etc. A lot of documentation described in this book is available only on national level, and the combination of this material in one single volume looks like a cross-cultural study dealing with art and science, and almost can serve as a travel guide in time and space.

The Editors thank Dr. Wayne Orchiston for help and support in collecting the papers.

Christiaan Sterken and Hilmar W. Duerbeck
Editors

ACRONYMS

AAHE	Astronomical Archives at Herstmonceaux Castle, England
ADS	Astrophysics Data System
AG	Astronomische Gesellschaft
BAAS	British Association for the Advancement of Science
CDS	Centre de Données astronomiques Strasbourg
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EAD	Encoded Archival Description
IAU	International Astronomical Union
IBS	Inventory Book for Survey
IIAB	Indian Institute of Astrophysics (Bangalore)
IUCAA	Inter University Centre for Astronomy and Astrophysics
KO	Kodaikanal Observatory (Kodaikanal)
MALVINE	Manuscripts and letters via Integrated Networks in Europe
MGAB	Maharashtra Govt. Archives (Bombay)
NAND	The National Archives (New Delhi)
NASA	National Aeronautics and Space Administration
NLO	Norman Lockyer Observatory
NSDAP	Nationalsozialistische Deutsche Arbeiterpartei
RAS	Royal Astronomical Society
RASL	Library of the Royal Astronomical Society (London)
RASNZ	Royal Astronomical Society of New Zealand
RSL	Library of the Royal Society (London)
UKATC	United Kingdom Astronomy Technology Centre
USNO	U.S. Naval Observatory

Part 1

ASTRONOMICAL ARCHIVES

. . . THAT THE UNION SUPPORTS THE INITIATIVES TAKEN BY THEM [COMMISSIONS 41 AND 5]

1. TO ESTABLISH A REGISTER OF THE WHEREABOUTS OF ALL EXTANT ASTRONOMICAL ARCHIVES OF HISTORICAL INTEREST;
2. TO IMPRESS ON OBSERVATORIES AND OTHER INSTITUTIONS THEIR RESPONSIBILITY FOR THE PRESERVATION, CONSERVATION, AND WHERE POSSIBLE, CATALOGUING OF SUCH ARCHIVES;
3. TO SEARCH FOR AN INSTITUTION THAT WILL ALLOCATE SPACE AND FUNDS FOR MAINTAINING SUCH A REGISTER AND PUBLISHING IT.

IAU RESOLUTION (1991 GENERAL ASSEMBLY)

ASTRONOMICAL HERITAGES: Astronomical Archives and Historic Transits of Venus
Journal of Astronomical Data, Vol. 10, 7, 2004
Christiaan Sterken, Hilmar W. Duerbeck, eds.

Astronomical Archives in India

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ABSTRACT

A brief overview is given of the activities of nine observatories (located at Madras, Lucknow, Trivandrum, Poona, Calcutta, Dehra Dun, Kodaikanal, and Hyderabad) which were established in India in the 19th century. A bibliography of publications of these observatories, sorted according to type of astronomical data, and some notes on observational material, is also presented.

1. Introduction

India with its long tradition of star catalogues, spectroscopy, spectrography, and astrophotography has a very rich archival material on astronomy. We may recall that the first modern observatory was built at Madras already in 1792 where initially a series of observation of stars, the moon and eclipses of Jupiter's satellites were commenced. We list the following Indian observatories, which were established and started working in the 19th century[1] (Ansari 1985). The years of establishment and abolition are given in parentheses.

1. Madras Observatory (1792–1900)

[1] S.M.R. Ansari, *Introduction of Modern Astronomy in India during the 18th–19th Centuries*, New Delhi, 1985. It is the corrected version of the article published originally in *Indian J. of History of Science*, Vol. 20 (1985) 363–402. In the sequel we refer to this publication just by Ansari (1985). For an earlier version, see S.M.R. Ansari, *On the Early Development of Western Astronomy in India and the Role of the Royal Greenwich Observatory*, Archives Internationales d'Histoire des Sciences, Vol. 27, No. 101 (1977), pp. 237–262 (Ansari 1977). This is the first detailed work based on archival sources on the modern astronomical observatories in India.

2. The Royal Observatory at Lucknow (1835–1849)
3. Raja of Travancore Observatory at Trivandrum (1842–1865)
4. Capt. W.S. Jacob's Observatory at Poona (1842–1862)
5. St. Xavier College Observatory at Calcutta (1875– ca. 1918)
6. Maharaja Takhtasinghji Observatory at Poona (1882–1912)
7. Hennessy Observatory at Dehra Dun (1884–1898)
8. Solar Observatory at Kodaikanal (1901–to date)
9. Nizamiah Observatory at Hyderabad (1901–1954)

Modern observatories, established after the independence of India in 1947, are not the subject of the present review; we refer to recent publications by Kochhar & Narlikar (1993) and Bhattacharyya & Vagiswari (1985).

We give in the following a brief account of the above-mentioned observatories where important astronomical results were achieved, and whose astronomical work became internationally known.

2. The Madras Observatory (1792–1900)

Established in 1792 through the efforts of Michael Topping (1747–1796), it was the first modern observatory. Active astronomical work was started when the Dane John Goldingham (d. 1849) was appointed as Government astronomer (1796–1830). He was followed by quite well-known astronomers: Thomas G. Taylor (1830–1848), William S. Jacob (1814–1858), and finally Norman R. Pogson (1861–1891). These astronomers started a series of observation of stars, the Moon, and eclipses of Jupiter's satellites. Later Madras Observatory became internationally known for its general star catalogues published in two volumes by Goldingham; of 11000 stars by Taylor, supplemented by 1440 stars observed by Jacob, and of 51101 stars carried out during 1862–1887 by Pogson (see Ansari 1985, p. 21–27, and the bibliography below). Pogson was also an expert in the observations of asteroids and variable stars. He discovered six minor planets during his tenure at Madras, and continued working on his *Variable Star Atlas.* We presume that the records of all his observations, in particular the astrophotographic plates should be available in Kodaikanal Observatory.

All these Government astronomers had a very active correspondence with the Astronomer Royal: N. Maskelyne, G.B. Airy, and W.H.M. Christie. This correspondence is very significant for the study of the development of modern astronomy in India (Ansari 1985, p. 43–47; Ansari 1977, p. 257–261).

The contribution of Maj. James F. Tennant, who was the director of Madras Observatory during 1859–1860[2] is also noteworthy (Ansari 1985, p. 25). His major contributions were the observation of the total solar eclipses of Aug. 17–18, 1868 at Guntoor and of Sept. 11–12, 1871 at Dodabetta (Nilgiri Hills) in India, as well as the transit of Venus in 1874 at Roorkey. He had specialized in the then new technique of photography. By that means, he found an 'unknown' yellow line in the solar spectrum, which was later identified by Sir Norman Lockyer as being due to the new element helium.

3. The Royal Observatory at Lucknow (1835–1849)

This observatory was founded by the Indian ruler of North providences *(Oudh*, modern *Awadh*), Nawab Nasiruddin Haydar (reign 1827–37), and Major Richard Wilcox was the director of the observatory during 1835–1848 (Ansari 1985, p. 29–33, where the whole story of its foundation and abolition after the death of Wilcox is given). We are concerned here with the astronomical work of Wilcox. He worked under the guidance of George Airy, the Astronomer Royal. His observations comprised major planets, the minor planets Ceres, Vesta, Pallas and Juno, eclipses of Jupiter's satellites, lunar occultations of stars, meridian observations of stars of the Nautical Almanac, etc. He also reduced his observations for the years 1841–43. However, we have not been able to find at present a record of those observations, apart from the volume of Lucknow Magnetic Observatory[3] (Ansari 1985, p. 33–34).

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[2]He was elected in 1869 as Fellow of the Royal Society, and President of the Royal Astronomical Society (UK) for 1890–91.

[3]We conjecture that they might be available in Dr. Alloy Sprenger's Collection. Dr. Sprenger was an Austrian Orientalist, who worked as the Principal of Delhi College, Delhi.

4. Raja of Travancore Observatory (1842–1865)

The observatory was founded by the Raja Rama Vurmah (modern Verma) at Trivandrum in 1837. The director of the observatory, John Caldecott, started astronomical observations in the same year. He collected a good deal of stellar data with the assistance of an Indian, trained by T.G. Taylor. These data were transferred to the Royal Society. We may mention here his observations of the solar eclipse of Dec. 21, 1843, carried out at the source of Mahe river, including observations of Bailey's beads. He also observed and computed the elements of the comets of 1843 and 1845. The former was the 'daytime' comet observed in March 1843[4]. The latter was 'Colla's comet' observed in June 1845 (Ansari 1985, p. 34–35; Broun 1857). Caldecott's observations of this comet were used by J.R. Hind[5] to calculate its orbit.

5. Capt. Jacob's Observatory (1842–1862)

A private observatory was founded by Capt. W.S. Jacob at Poona (modern Pune). It was in operation from 1842 to Jacob's death in 1862. The main work done by the founder was the observation of 244 double stars, of which he published a catalogue. He is also famous for his calculation of the orbits of a few binaries, e.g., α Centauri, and in particular for the triplicity of ν Scorpii in 1847 (Ansari 1985, p. 35–36).

6. St. Xavier College Observatory at Calcutta (1875–1918)

It was the *first* observatory with spectroscopic facilities under the directorship of Father Eugene Lafont (1837–1908), who joined the College in 1865. He started working in astronomy in 1874, when he took part in the expedition of the Italian astronomer P. Tacchini to observe the transit of Venus of Dec. 9, 1874 in Madhupur (Bihar). Father Lafont then set up the first spectroscopic laboratory in India, to record

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[4]The comet is important, since A.C.D. Crommelin in his *Comet Catalogue* (Memoirs of the British Astronomical Association, Vol. XXVI, Pt. 2, Perth, 1925) lists (Serial No. 198) its period as 512.39 years.

[5]Famous for his book: *The Comets: A descriptive treatise upon those bodies, with a condensed account of the numerous modern discoveries respecting them; and a Table of all the calculated comets from the earliest ages to the present time.* London, 1852.

solar and stellar spectra. To that end, he collaborated with Father A. Secchi (1818–1878), director of the Collegio Romano and founder of the *Società degli spettroscopisti Italiani* in 1867. In about 1877, a daily mapping of the solar prominences was carried out at the College Observatory.

Father Lafont, along with his assistant Father Alphonse de Penarande (d. 1896), carried out many observations: the motion of Mars (1879) and of a comet; recording the solar chromosphere during the solar eclipse of May 24, 1882 and of June 6, 1890 at Bhagalpur; the transit of Mercury on May 10, 1891 etc. Another Jesuit, Father V. de Campigneulles of the same College led an expedition to Dumraon (Bihar) to observe the total solar eclipse of Jan. 22, 1898 (Biswas 1994). He reported that the totality lasted 99 seconds, recorded solar prominences, inner and outer corona, the last one reflecting spectral lines of H, He, Ca, Fe, etc. De Campigneulles published two monographs on that important solar eclipse. According to our information, some records of these observations still exist at the College (Ansari 1985, p. 41).

7. Maharaja Takhtasinghji Observatory (1882–1912)

The observatory was sponsored and financed by the Maharaja Takhtasinghji of Bhavanagar at the instance of the Parsi physicist Kavasji Dadabhai Naegamwala (1857–1938), who had got his training of spectroscopic work at the solar physics laboratory of Sir Norman Lockyer (Ansari 1985, p. 36–40). Naegamwala was in fact the *first* Indian astrophysicist. His work at the observatory consisted of spectroscopy of the Orion Nebula, Nebula NGC 4594, 43 Virginis, NGC 6595, Nova Persei, besides his observation of the transit of Mercury on May 9, 1891 (Ansari 1985, p. 41). However, his most remarkable work was the meticulously planned expedition to record the solar chromosphere and corona at the time of the total solar eclipse on Jan. 22, 1898, at Jeur (Western India)[6]. The importance of that total solar eclipse, particularly for coronal photography, can be gauged from the fact that a Joint Eclipse Committee of the Royal Society and the Royal Astronomical

[6] See the bibliography for reference.

Society was set up, headed by the then Astronomer Royal Sir W.H.M. Christie, to undertake an expedition to India[7].

Naegamwala corresponded actively with Sir Christie and Sir Norman Lockyer. This historically important correspondence is still extant in the collection of MGAB (Ansari 1977, p. 256–257; Ansari 1985, p. 38–39), AAHE, and should also be at the archives of Lockyer Observatory at the University of Exeter, UK (Wilkins 2004).

8. Hennessy Observatory at Dehra Dun (1884–1898?)

This observatory is named after J.B.N. Hennessy, Deputy Surveyor General of the Trigonometric Branch of the Survey of India. It was built in 1884 with a facility for photoheliographic work. Sir Norman Lockyer visited it in 1898, when he came to India to observe the total solar eclipse of 1898. He noted the importance of the Observatory for its type of work. It is said that solar photographs were taken routinely from 1878 down to 1925 (Kochhar and Narlikar 1993, p. 27). We conjecture that the plates from these times might still be available in the record office of the Survey of India at Dehra Dun (Ansari 1985, p. 41).

9. Solar Observatory at Kodaikanal (1900 to date)

This observatory (hereafter Kodaikanal Observatory) was planned during the tenure of Michie Smith as the director of the Madras Observatory (1891–1899). It started functioning in 1901 as a solar observatory with Michie Smith as its first director. The observation programme comprised the examination of solar prominences around the solar limb and the spectra of sunspots. When John Evershed, famous for his effect, became its director (1911–1923), a programme of systematic observation of sunspot spectra was initiated[8]. Kodaikanal Observatory has to-date the most unique solar activity record, available on photographic plates, which is now a hundred years old. Recent daily observational data is being stored in computer, and the process of digitisation of older material has now started (Vagiswari 2000).

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[7] See the bibliography. Christie came to India with the expedition. Even Sir Norman Lockyer and Sir Alexander Pedler led a team to observe the eclipse at Viziadurg; see Ansari (1985), p. 72.

[8] For a summary of Evershed's work, see Bhattacharyya & Vagiswari (1985).

10. Nizamiah Observatory at Hyderabad (1901–1954)

The observatory founded by an Indian noble, Nawab Zafar Jung in 1901, was acquired by the 6th ruler (*Nizâm*) of Hyderabad State (Deccan), in 1908. It was attached to the Osmana University in 1991. The successive directors were A.B. Chatwood (1908–1914), R.J. Pocock (1914–1918), T.P. Bhaskaran (1918–1944), and Akbar Ali (1944–1960). This observatory participated in the international astrophotographic *Carte du Ciel* project, which continued up to 1964 (Chinnici 1999). Out of the 21 observatories that participated in the programme, Nizamiah Observatory was the *only Asian* observatory, which participated successfully in this international endeavour. In fact, the observatory replaced first Santiago Observatory (Chile) in 1909, and later was asked to cover also another sky zone originally assigned to Potsdam Observatory (Ansari 2000). In short, this astrographic data covers the sky zones $-17°$ to $-23°$ and $+36°$ to $+39°$ (Bhattacharyya & Vagiswari 1985, Kochhar & Narlikar 1993). This work comprised also measurements of 763,542 stars on the plates, which were published in 12 volumes. Besides that, a programme of observations of variable stars and of measurements of double stars was also initiated at Nizamiah Observatory (Ballabh 1983).

11. Concluding Remarks

Summing up, we may reiterate that an enormous amount of astronomical data of the 20th century, which was generated in a number of Indian observatories, is still available in India and abroad. At Kodaikanal Archives some documents are nearly 200 years old. More than 5000 pages have been digitised and are available at CDS (Vagiswari 2000). The Centre of Advanced Computing (Pune) is also cooperating in this effort (Sagar 2000). An astronomical data centre in collaboration with Strassbourg Data Centre had been established at the Inter University Centre for Astronomy and Astrophysics (IUCAA) in Pune (Vagiswari 2000). We may mention in passing that the problem of data archives was recently discussed at a two-day workshop on "Front-end Controls and Data Archival for Indian Telescopes", which was held in Pune on Jan. 29–30, 2004. Plans are also afoot for the so-called "Virtual Observatory–India Project", which is being promoted at IUCAA (Kemhavi 2004). It is hoped that the Indian Observatories will be able to transfer electronically their data to this VO-project.

For easy reference, a bibliography of publications concerning Indian Astronomical Data, arranged according to the nature of the data, is attached to this article.

Acknowledgements

The author acknowledges the cooperation of Prof. Ram Sagar (Nanital), Ms. A. Vagiswari (Bangalore) and Prof. Ajit Kembhavi (Pune). Thanks are also due to Prof. F.R. Stephenson (Durham) to give me the opportunity to participate at JD6 (archive session) at the 24^{th} IAU General Assembly, in Manchester in 2000.

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Sagar, R. 2000, private communication, dated 30 May.

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Wilkins, G.A. 2004, JAD 10, 7 (These Proceedings p. 153).

[9]see `http://vo.iucaa.ernet.in/~voi/`

Abbreviations for Archives in India and abroad:

AAHE	Astronomical Archives at Herstmonceaux Castle (England)
IIAB	Indian Institute of Astrophysics (Bangalore) [est. 1971]
KO	Kodaikanal Observatory (Kodaikanal)
MGAB	Maharashtra Govt. Archives (Bombay)
NAND	The National Archives (New Delhi)
RASL	Library of the Royal Astronomical Society (London)
RSL	Library of the Royal Society (London)

Star Catalogues

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Jacob, W.S., MNRAS 8 (1848), 17 (1857) and 22 (1862). The data therein concern double stars.

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Nizamiah Observatory, *An Astrographic Catalogue of Stars for the Sky Zones −17° to −23°, and +36° to +39°*, Hyderabad (India), 12 Volumes, 1919–1951. [We conjecture that the photographic plates should be available in the Jappal-Rangapur Observatory of the Dept. of Astronomy, Osmania University, Hyderabad].

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Solar Activity Data

Sohini, V.V., *Reports of the Kodaikanal Observatory* 1901–1951, India Meteorological Dept., New Delhi. [These Reports by various directors, including Evershed and his predecessors contain a mine of information; see also *Kodaikanal Observatory Bulletins* of 1920s and 1930s, for the record of observations and data].

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Journal of Astronomical Data, Vol. 10, 7, 2004
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Archives at the U.S. Naval Observatory – Recent Projects

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Abstract

In 1874, like many other astronomical institutions, the U.S. Naval Observatory sent eight expeditions to different parts of the globe to observe the Transit of Venus. After all results were in, William Harkness was placed in charge of preparing the results and observations for publication. Page proofs of these observations appeared in 1881, but due to lack of funds and other reasons, these volumes were never published. Recently funds became available to have photocopies made on acid-free paper. The Astrophysics Data System (ADS) agreed to scan the photocopied pages and has made this publication available via the ADS so it now may be seen by anyone with access to the web.

The compilation of a historical photograph archive at the USNO is continuing. Photographs and glass plates are being scanned by students and placed on the web. As the Naval Observatory has many thousands of plates and photographs, this project will take quite some time to complete. The images are of instruments, buildings, and staff members. The URL for this collection is `http://www.usno.navy.mil/library/search.shtml`

A project currently under consideration is moving most of the archives now residing at USNO to the National Archives. A few of the reasons for this possible move include better preservation facilities available at the National Archives, better long-term storage and access for scholars, and guaranteed safety of this collection.

Figure 1. U. S. Naval Observatory Library, Washington, D.C.

1. 1874 Transit of Venus

1.1. Preparation for the Transit

In 1874 major observatories all over the world sent teams of astronomers to observe this event. The scientific purpose of these expeditions was to accurately measure the distance between the Earth and the Sun. The American Transit of Venus Commission working with the U.S. Naval Observatory (USNO) sent expeditions to eight distant locations for this important celestial event: Vladivostok, Nagasaki, Peking, Hobart Town, Queenstown, Kerguelen Island, Campbell Town and the Chatham Islands. All teams gathered at the U.S. Naval Observatory in the Spring of 1874 to practice with the instrumentation supplied for the Transit. Each team was issued the same equipment including a $f/77$ horizontally mounted photoheliograph with a 7-inch Alvan Clark lens, and a 5-inch telescope also made by Alvan Clark. Some information on the photoheliographs is given in Section 3.4; three almost complete 5-inch refractors have survived and two are currently on display at the Observatory, and one is on loan to the Smithsonian's National Museum

Figure 2. Practice for Transit of Venus at U. S. Naval Observatory, Spring, 1974. Standing at left: ADM C. H. Davis (founder, American Nautical Almanac Office); (standing in front of Davis) Henry Draper and C. H. F. Peters (with hat); Simon Newcomb (seated front left wearing cap); Asaph Hall (in front of ladder, arms folded); Albert A. Michelson (seated 3rd from the right); at far right (with stovepipe hat) William F. Gardner, the Observatory's instrument maker.

of American History for the exhibit "Chasing Venus". This exhibit is on view through March 2005.

The Archives house the metal black boxes that were issued to each team. These boxes held the instructions for the instruments, log books for recording observations and other papers relating to the expeditions. Many of these boxes are currently on loan to the Smithsonian for the exhibit that can be seen on the web[1].

---

[1] `http://www.sil.si.edu/exhibitions/chasing-venus/intro.htm`

Figure 3. Alvan Clark 5-inch refractor. Eight of these were produced for the 1874 Transit of Venus expeditions.

1.2. Harkness and the Observations

Observations from all eight of the Naval Observatory expeditions were returned to Washington and William Harkness was placed in charge of preparing the observations for publication. Meanwhile, the Naval Observatory also sent teams to observe the 1882 Transit of Venus but on a smaller scale than in 1874. Harkness spent many years in preparing the 1874 observations, and finally in 1881 the Observations volume was actually set in type and the page proof copy delivered to the Observatory. However, the observations were never published.

The reasons the volume was not published are not totally clear, but certainly lack of funding was one of the reasons. In the memo below dated March 1891 (10 years after the page proof was delivered to the Observatory) Harkness reports "...at least a year would be necessary

Figure 4. Metal boxes that went to each expedition site.

to prepare the printer's copy and get the work through the press..." Unfortunately, a note at the bottom of these minutes states that this was the last meeting of the Transit of Venus Commission. Simon Newcomb's name is on the title page of this unpublished volume and under his name is "Secretary of the Commission". This unpublished work has always resided in the Naval Observatory Library. Until recently, only researchers who visited the Library could see these results.

1.3. Scanning of Page Proof Volume and Availability through ADS

In 2002, the librarian sought funding to make preservation photocopies of this volume on acid-free paper. The rare volume was sent to a book conservation facility where the work was done. With copies now available, the librarian approached the Astrophysics Data System (ADS) and asked if they would be willing to scan the photocopy and make the complete volume available via ADS, and they readily agreed. Special thanks go to the ADS for their willingness to do this, and especially to Alberto Accomazzi of ADS who gave this project priority so that availability of this online document could be announced to Commission 41 (History of Astronomy) at the meeting of the General Assembly of

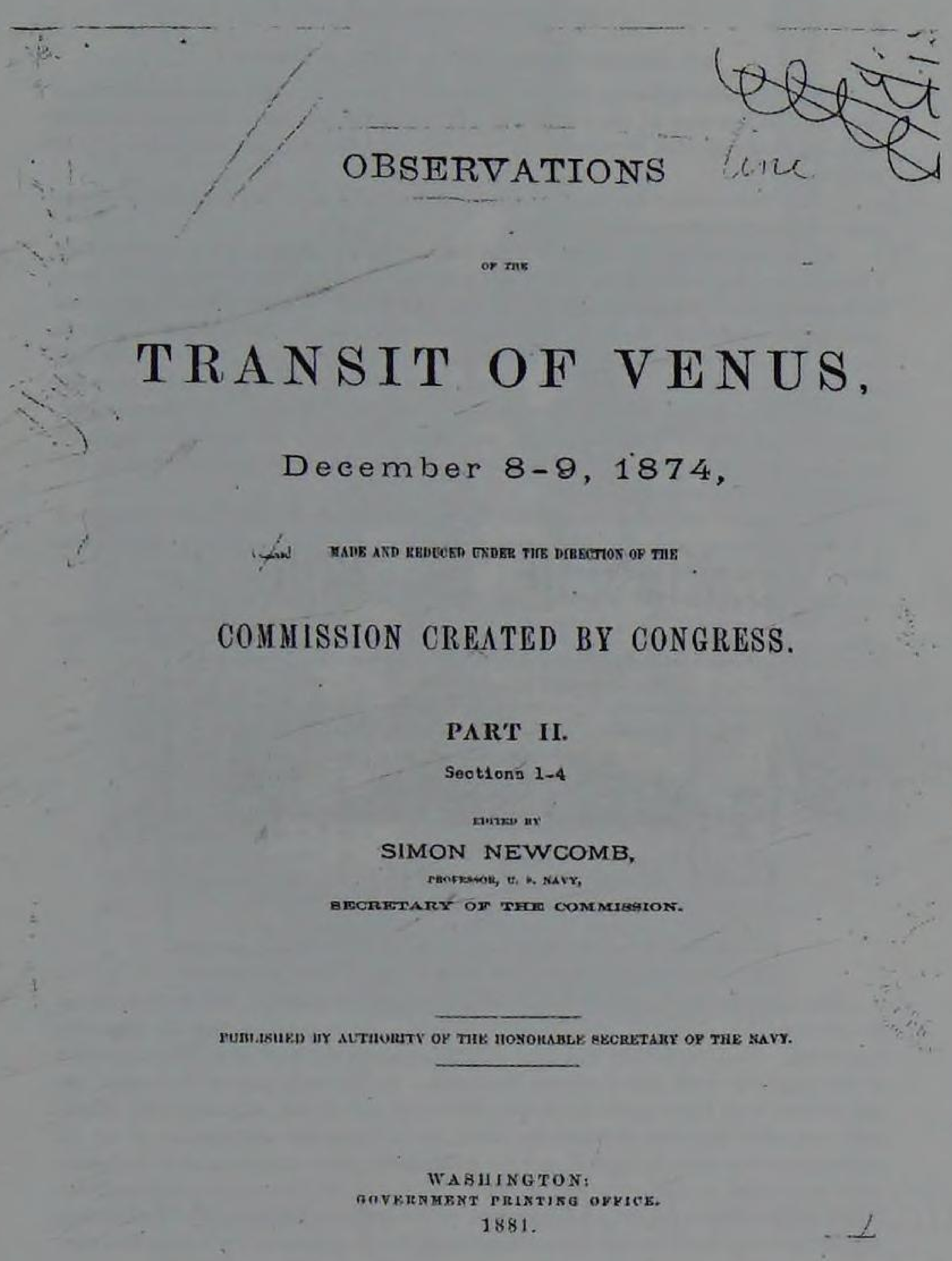
Figure 5. *Left:* William Harkness, astronomer in charge of collecting all the 1874 transit observations. *Right:* Simon Newcomb, Secretary of the Transit of Venus Commission. This oil portrait hangs in the Naval Observatory Library.

the International Astronomical Union (IAU) in Sydney, August 2003. These Transit of Venus Observations previously seen by only a small number of people are now available to everyone via the ADS. A record for the volume now available through the ADS is given below:

NASA ADS Astronomy Abstract Service

Title:	Observations of the Transit of Venus, December 8–9, 1874
Authors:	Newcomb, Simon
Journal:	Observations of the Transit of Venus, December 8–9, 1874, p. 1–564
Publication Date:	00/1881
Origin:	AUTHOR
Bibliographic Code:	1881otv..book....1N

The Naval Observatory has a large number of archival photographs showing the instruments, buildings and grounds and astronomers. This is an ongoing project as photos are scanned and placed online. Summer students working in a special science apprentice program are mainly carrying out this task. The library does not have enough staff to de-



OBSERVATIONS

OF THE

TRANSIT OF VENUS,

December 8-9, 1874,

MADE AND REDUCED UNDER THE DIRECTION OF THE

COMMISSION CREATED BY CONGRESS.

PART II.

Sections 1-4

EDITED BY

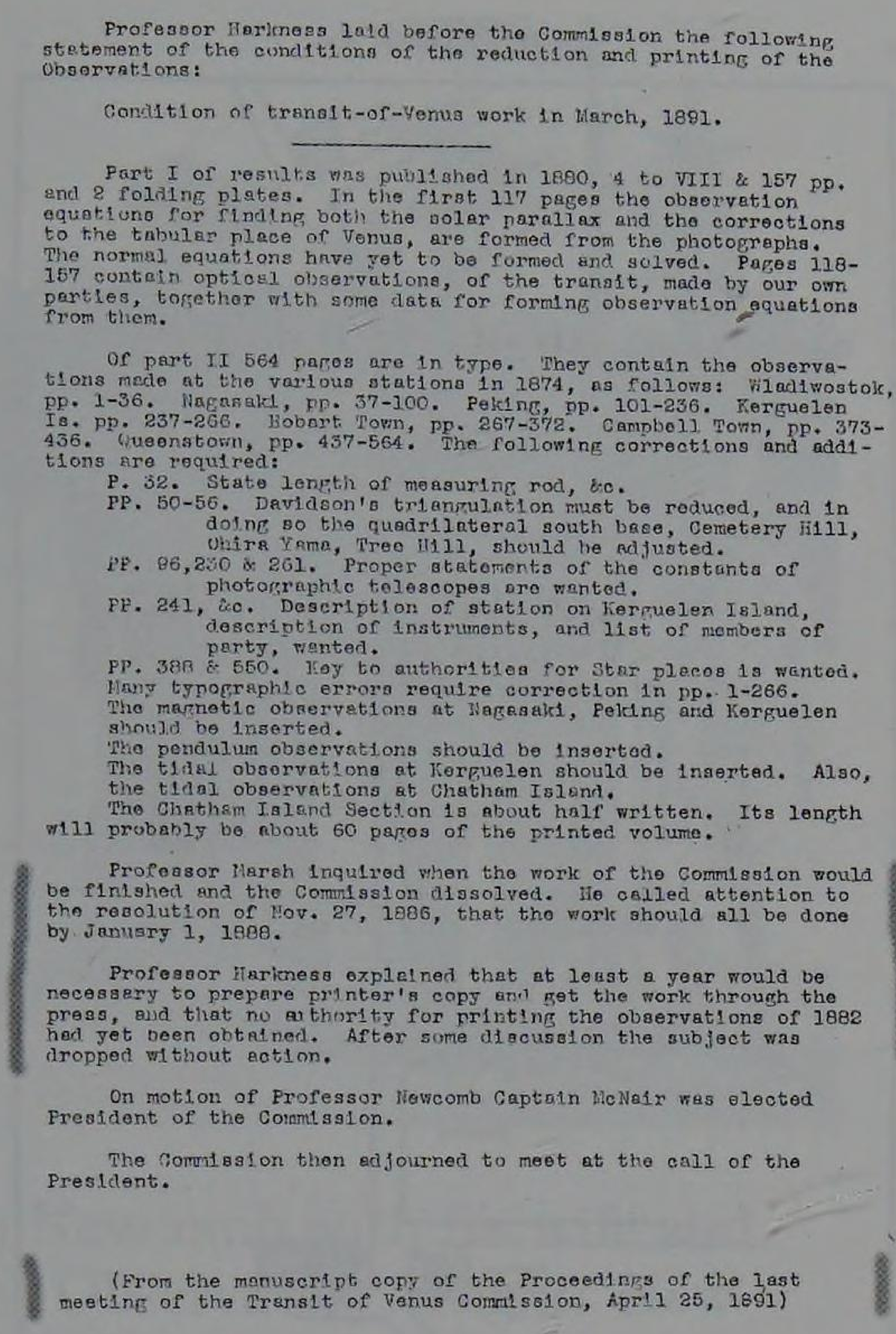
SIMON NEWCOMB,

PROFESSOR, U. S. NAVY,

SECRETARY OF THE COMMISSION.

PUBLISHED BY AUTHORITY OF THE HONORABLE SECRETARY OF THE NAVY.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1881.



Professor Harkness laid before the Commission the following statement of the conditions of the reduction and printing of the Observations:

Condition of transit-of-Venus work in March, 1891.

Part I of results was published in 1880, 4 to VIII & 157 pp. and 2 folding plates. In the first 117 pages the observation equations for finding both the solar parallax and the corrections to the tabular place of Venus, are formed from the photographs. The normal equations have yet to be formed and solved. Pages 118-157 contain optical observations, of the transit, made by our own parties, together with some data for forming observation equations from them.

Of part II 564 pages are in type. They contain the observations made at the various stations in 1874, as follows: Wladiwostok, pp. 1-36. Nagasaki, pp. 37-100. Peking, pp. 101-236. Kerguelen Is. pp. 237-266. Hobart Town, pp. 267-372. Campbell Town, pp. 373-436. Queenstown, pp. 437-564. The following corrections and additions are required:

P. 32. State length of measuring rod, &c.
PP. 50-56. Davidson's triangulation must be reduced, and in doing so the quadrilateral south base, Cemetery Hill, Ohira Yama, Tree Hill, should be adjusted.
PP. 96,230 & 261. Proper statements of the constants of photographic telescopes are wanted.
PP. 241, &c. Description of station on Kerguelen Island, description of instruments, and list of members of party, wanted.
PP. 388 & 550. Key to authorities for Star places is wanted.
Many typographic errors require correction in pp. 1-266.
The magnetic observations at Nagasaki, Peking and Kerguelen should be inserted.
The pendulum observations should be inserted.
The tidal observations at Kerguelen should be inserted. Also, the tidal observations at Chatham Island.
The Chatham Island Section is about half written. Its length will probably be about 60 pages of the printed volume.

Professor Marsh inquired when the work of the Commission would be finished and the Commission dissolved. He called attention to the resolution of Nov. 27, 1886, that the work should all be done by January 1, 1888.

Professor Harkness explained that at least a year would be necessary to prepare printer's copy and get the work through the press, and that no authority for printing the observations of 1882 had yet been obtained. After some discussion the subject was dropped without action.

On motion of Professor Newcomb Captain McNair was elected President of the Commission.

The Commission then adjourned to meet at the call of the President.

(From the manuscript copy of the Proceedings of the last meeting of the Transit of Venus Commission, April 25, 1891)

Figure 6. *Left:* Title page of the page proof volume which was never published. *Right:* Minutes of last meeting of the Transit of Venus Commission on April 25, 1891.

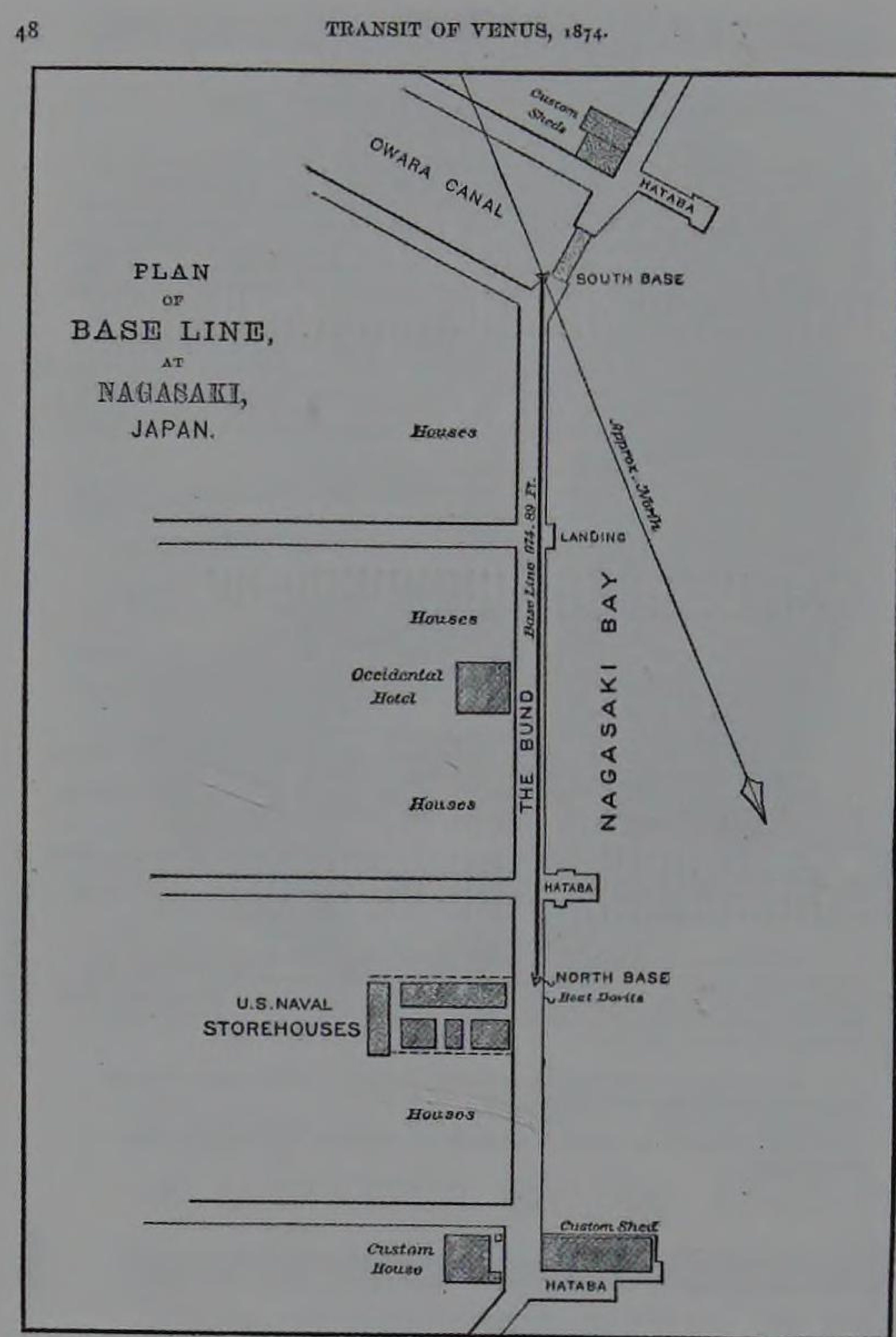
vote time to the project throughout the year and thus depends on the summer students for this project[2].

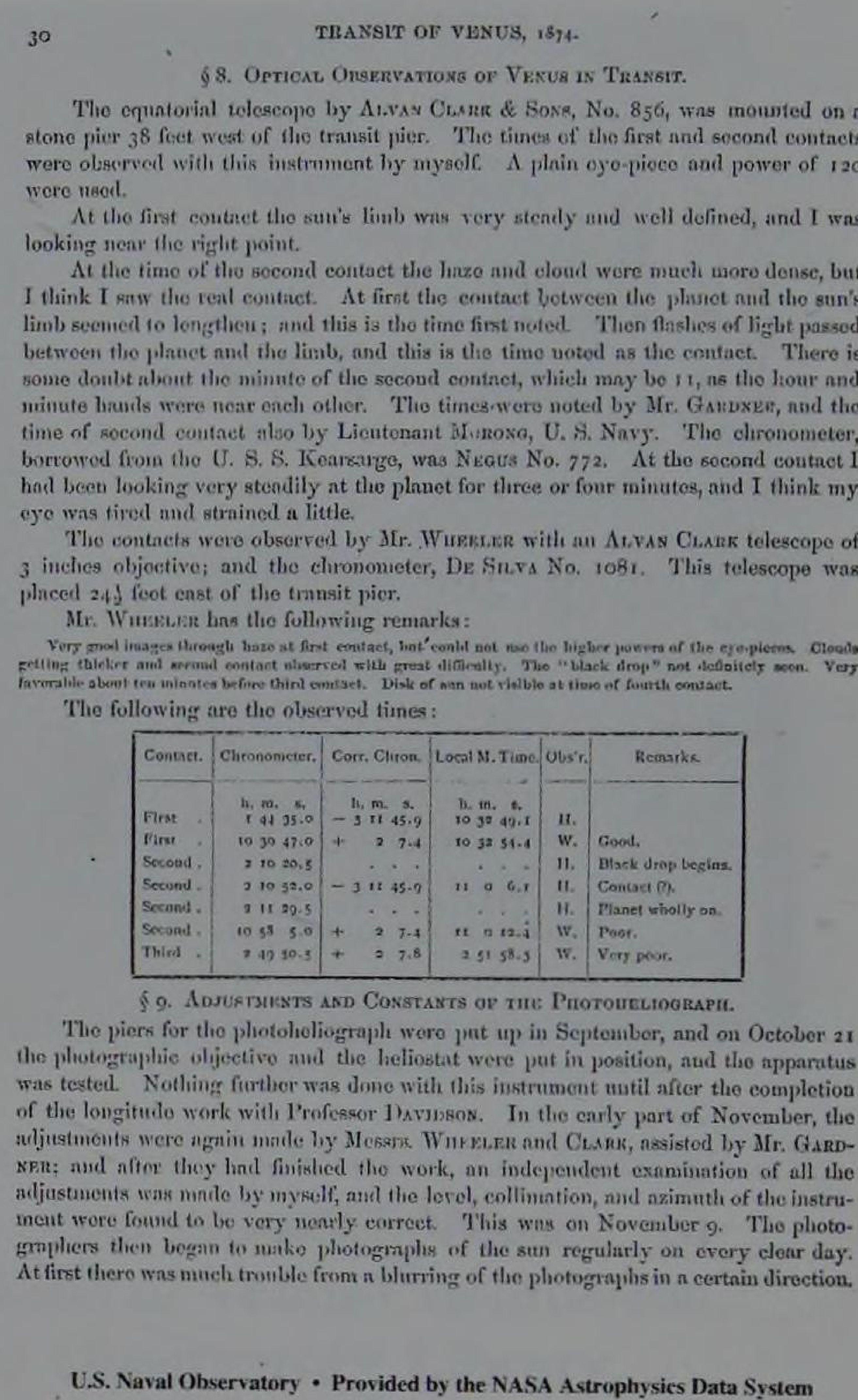
2. U. S. Naval Observatory Historical Photograph Archive

2.1. The Archival Photograph Project

The photos are housed in acid-free envelopes and acid-free boxes. The USNO has many thousands of photographs and it is estimated the project is currently about one third complete. In addition to paper photographs, the collection also includes glass plates, slides, lantern slides and some 19$^{\text{th}}$ century stereo cards. A few examples from the collection are shown below.

[2]The site is at `http://www.usno.navy.mil/library/search.shtml`




30 TRANSIT OF VENUS, 1874.

§ 8. Optical Observations of Venus in Transit.

The equatorial telescope by Alvan Clark & Sons, No. 856, was mounted on a stone pier 38 feet west of the transit pier. The times of the first and second contacts were observed with this instrument by myself. A plain eye-piece and power of 120 were used.

At the first contact the sun's limb was very steady and well defined, and I was looking near the right point.

At the time of the second contact the haze and cloud were much more dense, but I think I saw the real contact. At first the contact between the planet and the sun's limb seemed to lengthen; and this is the time first noted. Then flashes of light passed between the planet and the limb, and this is the time noted as the contact. There is some doubt about the minute of the second contact, which may be 11, as the hour and minute hands were near each other. The times were noted by Mr. Gardner, and the time of second contact also by Lieutenant Morong, U. S. Navy. The chronometer, borrowed from the U. S. S. Kearsarge, was Negus No. 772. At the second contact I had been looking very steadily at the planet for three or four minutes, and I think my eye was tired and strained a little.

The contacts were observed by Mr. Wheeler with an Alvan Clark telescope of 3 inches objective; and the chronometer, De Silva No. 1081. This telescope was placed 24½ feet east of the transit pier.

Mr. Wheeler has the following remarks:

Very good images through haze at first contact, but could not use the higher powers of the eye-pieces. Clouds getting thicker and second contact observed with great difficulty. The "black drop" not definitely seen. Very favorable about ten minutes before third contact. Disk of sun not visible at time of fourth contact.

The following are the observed times:

Contact.	Chronometer.	Corr. Chron.	Local M. Time.	Obs'r.	Remarks.
	h. m. s.	h. m. s.	h. m. s.		
First .	1 44 35.0	− 3 11 45.9	10 32 49.1	H.	
First .	10 30 47.0	+ 2 7.4	10 32 54.4	W.	Good.
Second .	2 10 20.5	. . .	. . .	H.	Black drop begins.
Second .	2 10 52.0	− 3 11 45.9	11 0 6.1	H.	Contact (?).
Second .	2 11 29.5	. . .	. . .	H.	Planet wholly on.
Second .	10 58 5.0	+ 2 7.4	11 0 12.4	W.	Poor.
Third .	2 49 50.5	+ 2 7.8	2 51 58.3	W.	Very poor.

§ 9. Adjustments and Constants of the Photoheliograph.

The piers for the photoheliograph were put up in September, and on October 21 the photographic objective and the heliostat were put in position, and the apparatus was tested. Nothing further was done with this instrument until after the completion of the longitude work with Professor Davidson. In the early part of November, the adjustments were again made by Messrs. Wheeler and Clark, assisted by Mr. Gardner; and after they had finished the work, an independent examination of all the adjustments was made by myself, and the level, collimation, and azimuth of the instrument were found to be very nearly correct. This was on November 9. The photographers then began to make photographs of the sun regularly on every clear day. At first there was much trouble from a blurring of the photographs in a certain direction.

U.S. Naval Observatory • Provided by the NASA Astrophysics Data System

Figure 7. *Left:* Map of the Nagasaki site from the page proof volume. *Right:* Page from the text as shown on ADS reporting observations from Vladivostok.

The photo database is being moved to newer software that can be more easily managed. There is also a need to add standardized indexing terms to the records, but there is currently not enough staff time to start this indexing project. The idea is to have the photographs available online, even though the text and search terms might not be perfect as yet. The long-term plans call for adding images from rare books and images of antique clocks and globes belonging to the Observatory to this database.

3. The Future of the Naval Observatory Archives

3.1. Possible move to the National Archives

A plan is under consideration to move the archives currently at the USNO to the National Archives and Records Administration (NARA)

Figure 8. *Left*: A young Simon Newcomb with his wife and 3 daughters outside the old Naval Observatory. *Right*: Newcomb with his wife and 2 grandchildren.

which now holds many of the USNO 19th century archives and also holds the Transit of Venus Commission records in Record Group 78. There are several reasons for considering this move. The position of historian at the USNO has been abolished due to budget constraints. Steven J. Dick, our former historian who published the history of the USNO in *Sky and Ocean Joined: The U. S. Naval Observatory, 1830–2000.* (Cambridge Univ. Press, 2003, ISBN 0521815991) is now Chief Historian at the National Aeronautics and Space Administration (NASA). It appears there are no plans to re-establish the USNO historian position in the future so there is no person directly in charge of the archives with time to care for them. The National Archives offers better preservation facilities, better long-term storage and access to scholars, and the safety of the collection would be guaranteed.

3.2. Recent Damage in Archives Room

In February 2004, a leak started in the archives room on a Saturday and was not discovered until that Tuesday. Although no archival material seemed to have been damaged, mold was present under the floor and in the walls and the room was sealed off until mold remediation could be

completed. This episode showed what possible disasters can happen, and it is felt the archives would be better protected in a national facility. The drawback to this move is that our own historical records will not be at our fingertips and extra effort must be made for the staff to view the archives.

3.3. Astronomical Glass Plates

The Naval Observatory has a large number of astronomical glass plates in various storage areas throughout the observatory, most of which are not properly climate controlled. A recent leak in another building where plates are stored destroyed some of the plates, and led the USNO History Committee to consider whether all USNO astronomical plates should be moved to the National Archives. This discussion is still underway. Most of the plates are housed in acidic paper sleeves and need to be transferred to acid-free sleeves. However, all the information on each old sleeve must be copied onto a new envelope. This is a daunting task with no staff or funding to carry out the project. In addition, the plates need to be carefully inventoried by telescope and observing project. It is clear that this same problem is facing other observato-

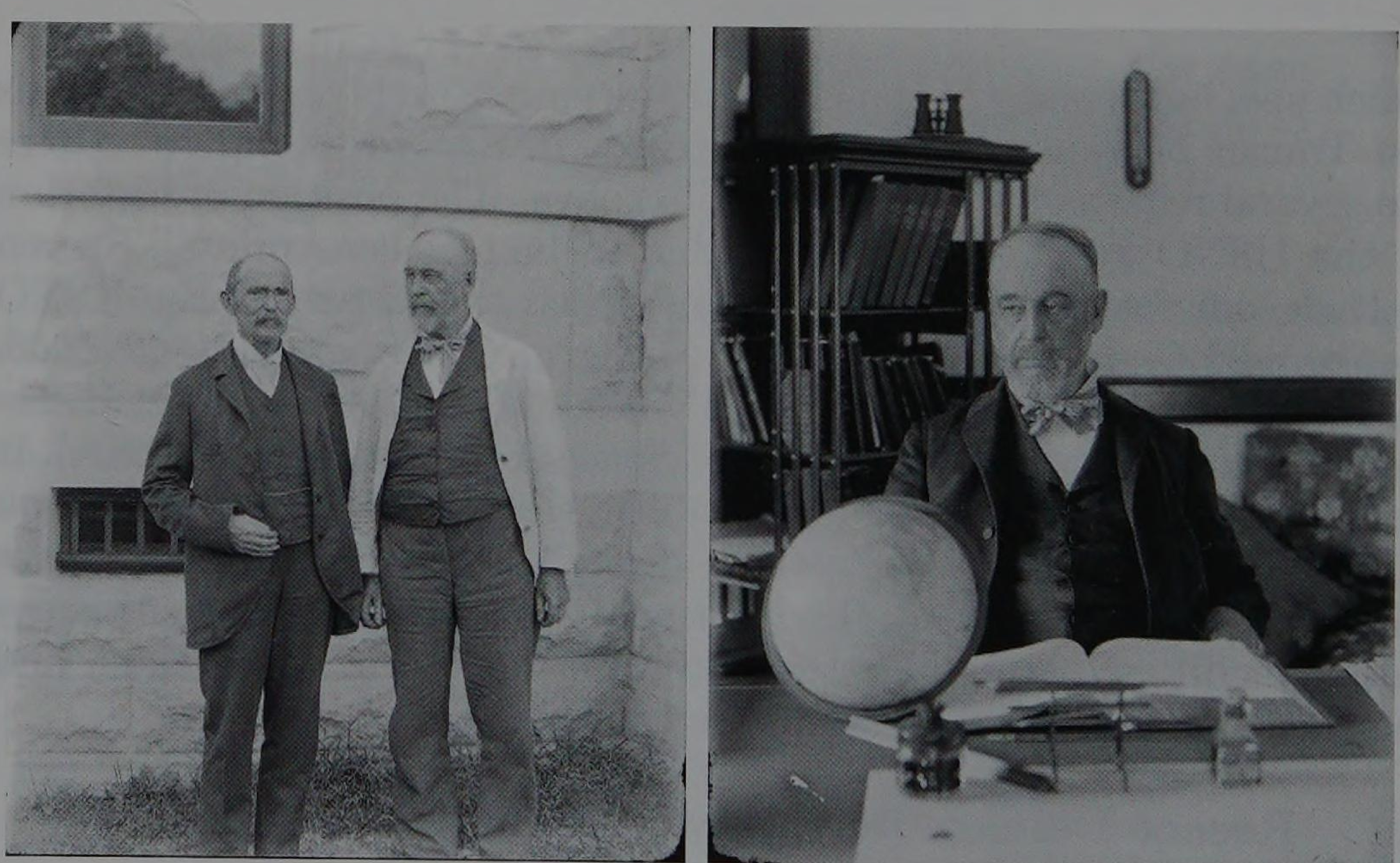


Figure 9. *Left*: Asaph Hall (right), discoverer of the moons of Mars with his observing assistant, George Anderson. *Right*: Asaph Hall as an older man with a globe of Mars on his desk.

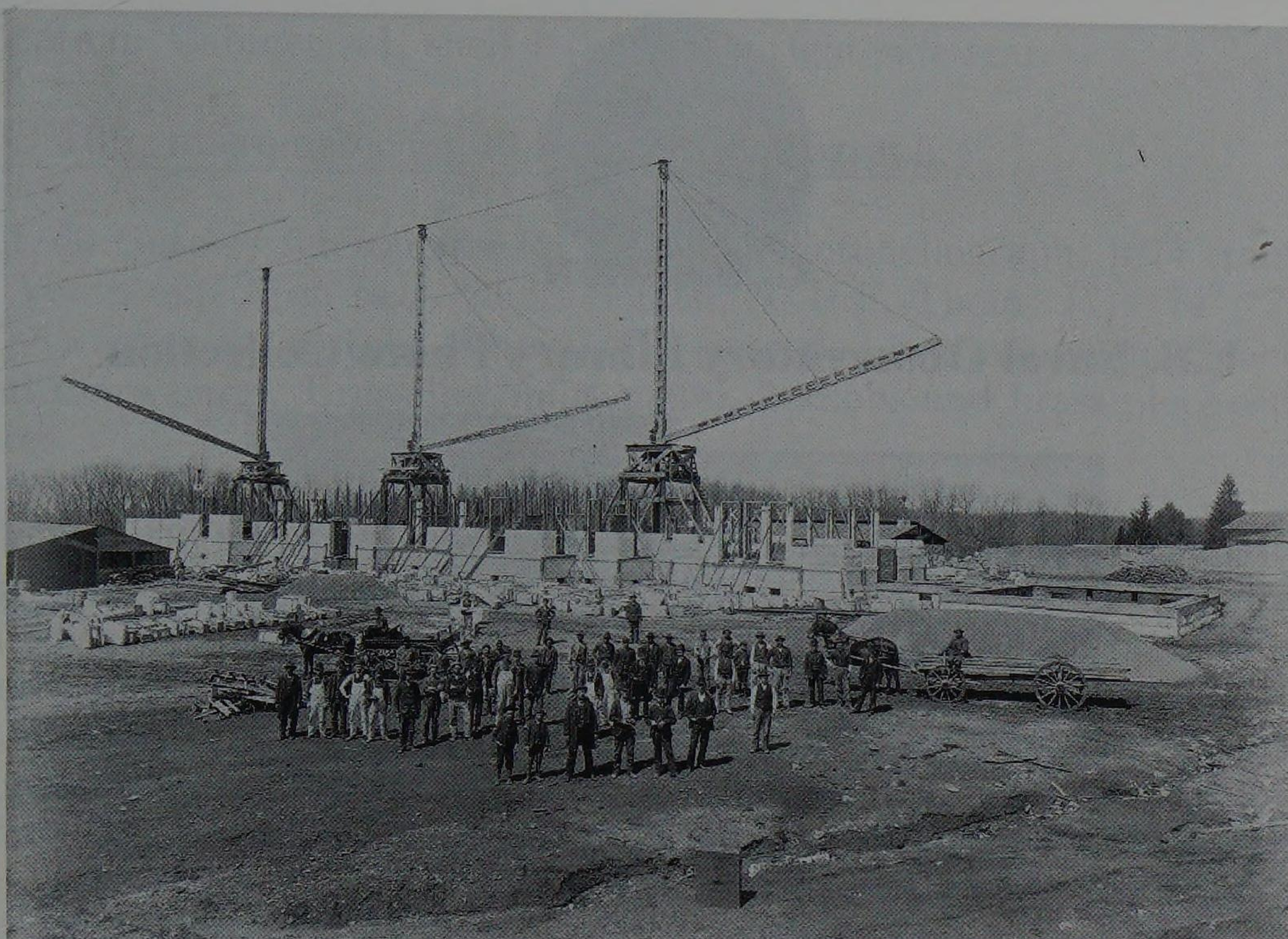


Figure 10. Construction of the new Naval Observatory at Georgetown Heights, 1880s.

ries throughout the world, and groups within IAU Commission 41 have discussed the possibility of a central storage site for plates. It is clear that some action must be taken as many administrators do not see any value in keeping older plates and they are in danger of being disposed of.

3.4. Historical Astronomical Instruments

The USNO has a collection of historic instruments stored in the basement of the main building. This collection includes lenses from older telescopes, measuring engines and equipment, and many other types of instruments. A few years ago a dedicated team of USNO astronomers interested in this equipment made a detailed inventory (several entries shown below) of every item found including all historic clocks on the grounds. Several large-scale work projects have taken place at USNO where outside workmen, without the knowledge of the staff, have moved these instruments and equipment around with some damage resulting. The History Committee is also considering whether some of these his-

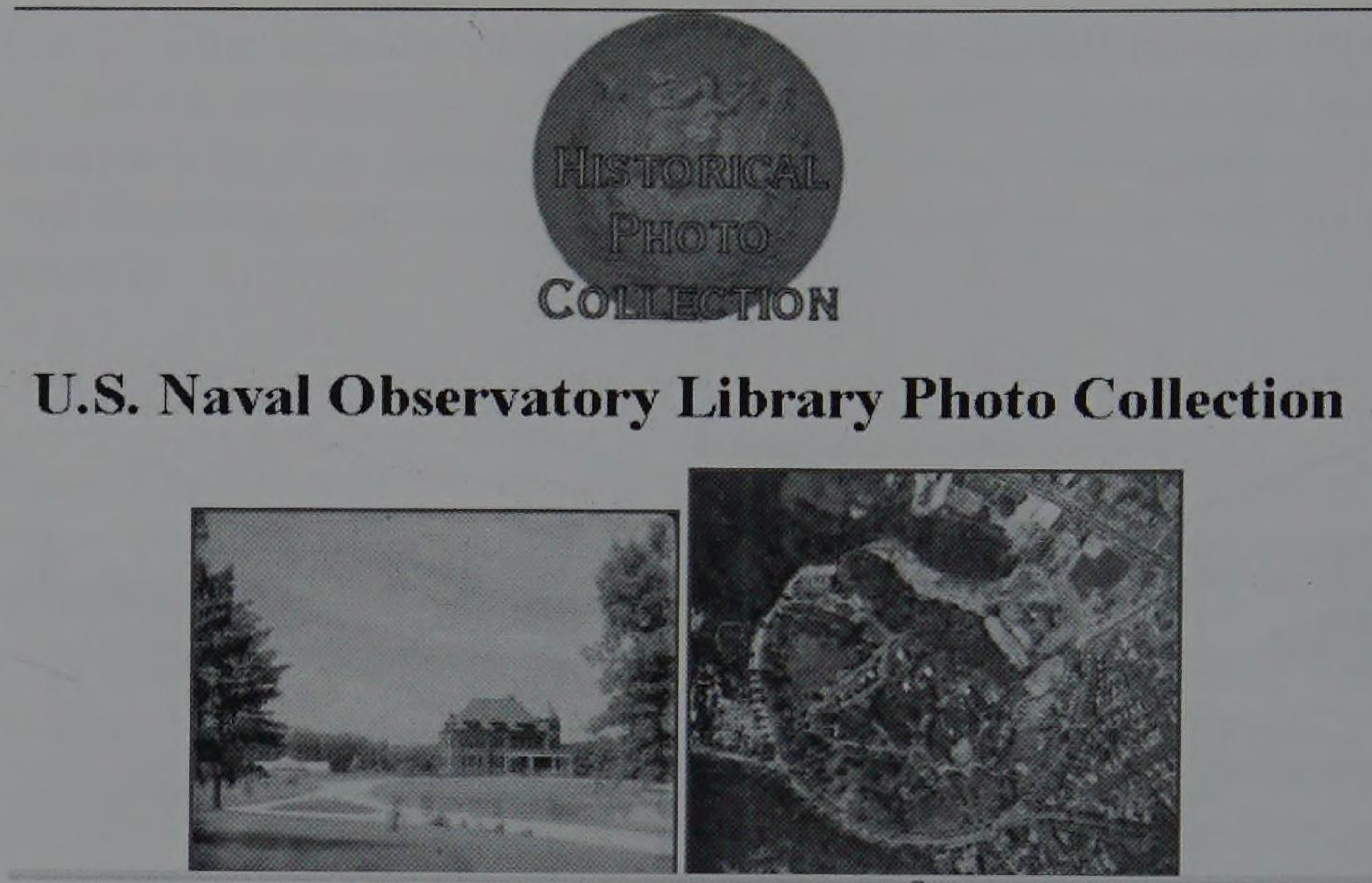


Figure 11. USNO historical photograph database web site.

toric items should be moved to the Smithsonian Institution for safekeeping. However, it is not clear if the Smithsonian would want everything that USNO considers historical. This discussion is still underway.
Several entries from the *Draft Property Inventory of the U. S. Naval Observatory History Committee as of September 26, 1996* by Brent A. Archinal.

HC 101 : 7.5″ triplet, $f/104$

"7$\frac{1}{2}$ in Objective Triple Combination", "US Naval Ob'sy", "Washington, D. C.", "J. A. Brashear Co. Ltd., Allegheny, Pa" (on box). "7.5 in, 65 feet, 1905" (on paper).

brass cell, with plate "John A. Brashear Co, Ltd. Allegheny, Pa", leather lens cover.

In wooden box (**HC 102**), 14″ × 14″ × 5$\frac{1}{2}$″, padded with red carpet, wooden rack.

Condition: Fair; glass very dusty, some smudges; brass has some corrosion, leather has some mold inside.

Location: Cabinet #1, shelf 1 (bottom), right side rear.

HC 105: micrometer for 40 foot photoheliograph

"11/60 Gate // micrometer for // 40-ft. photoheliograph, 1874 transit of Venus exp." (on tag). "Fort Selden, N. U.F. Thom" (?) "74","72" (?) (written on bottom of box). "7" (stamped in brass on micrometer and extra part). Brass jaw micrometer, 2 knobs and brass piece separate.

[Skinner [1898, p. 62 and p. 70] mentions jaw micrometers for use with the transit of Venus photoheliographs. The "Fort Selden" indicates this particular micrometer (or at least the box) was probably at Cerro Roblero, New Mexico during the 1882 transit of Venus. The "7" is clearly the identifying number (of 8 micrometers) – however Skinner does not list the observing locations of the micrometers by number.] [For information on the photoheliograph, see Warner and Ariail [1996, pp. 168–169].]

In wooden box (**HC 106**), 6″ × 6″ × 2.5″, oak?, 2 clasps.

Location: Cabinet #1, shelf 1 (bottom), center front

HC 113: partial 6″ cell

outer part of 6″ i.d. brass lens cell.

"B. H. Chatham Ltd" or "VII Chatham Ltd"? and illegible signature (script scratched on back). "3840" on side [Probably refers to "Chatham Ild" (Island). B.A.]. Same as front of **HC 118**.

Skinner [1898, p. 70–72] describes the eight Clark photoheliographs. It would appear that this cell was part of the lens no. "7", used to observe the 1874 transit of Venus from Whangaroa, Chatham Is., and the 1882 transit from Auckland, New Zealand.

3.5. The Future of USNO Archival Projects

The next few years will determine the future of USNO preservation projects. If the archives can be successfully transferred to the National Archives, and a safe site can be found for the astronomical plates

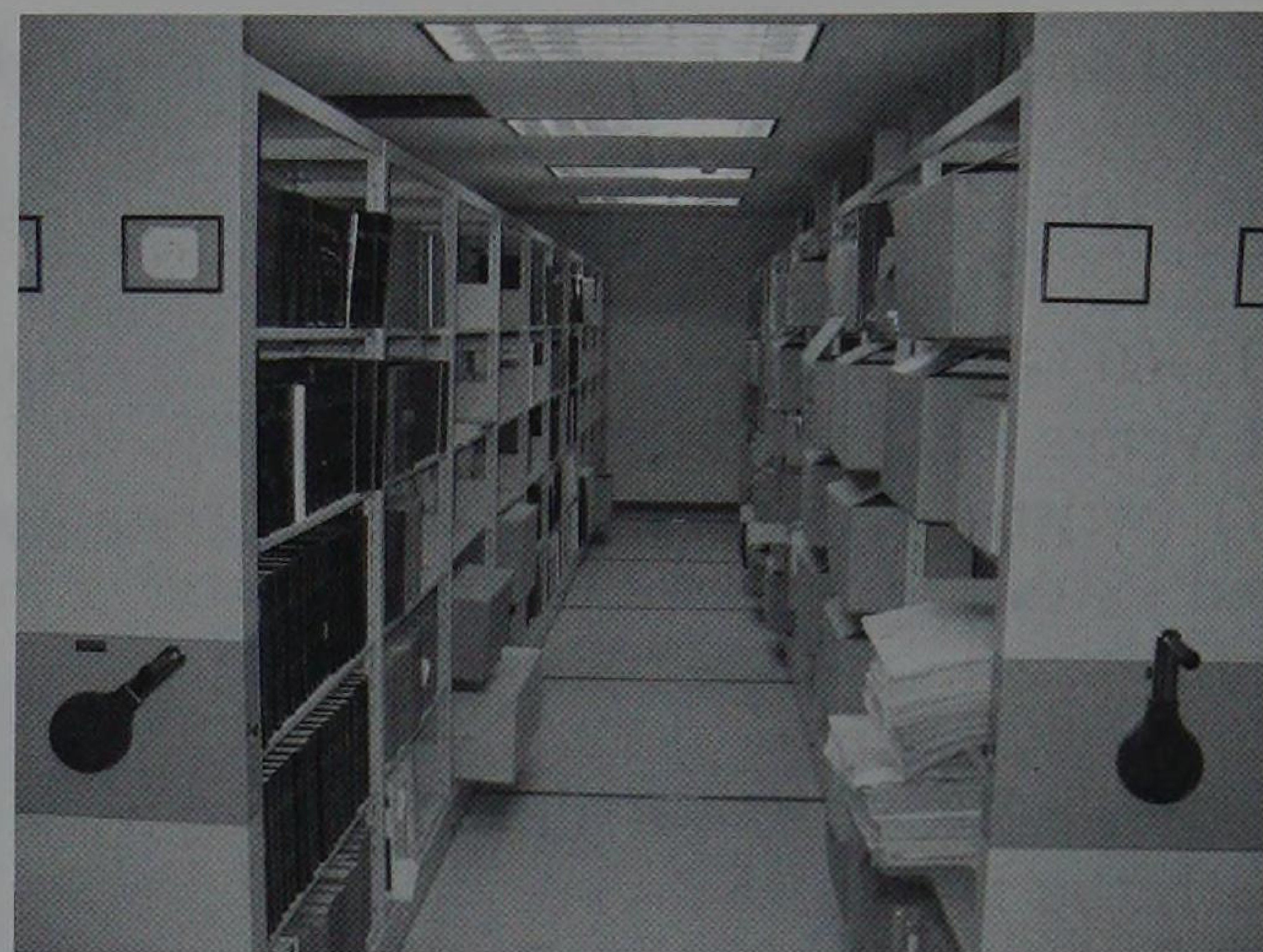



Figure 12. *Left*: photograph collection stored in acid-free boxes in the Library. *Right:* view, archives room.

and historical instruments, these collections will survive for future researchers to use. The historical photographs will most likely stay at the Naval Observatory, housed in the library. If the complete collection is online, it will be available to everyone and also preserved in that manner.

ASTRONOMICAL HERITAGES: Astronomical Archives and Historic Transits of Venus
Journal of Astronomical Data, Vol. 10, 7, 2004
Christiaan Sterken, Hilmar W. Duerbeck, eds.

The French Astronomical Archives Alidade Project

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ABSTRACT

The present state of Alidade, an archival project of Paris Observatory, including not only archival papers, but also instruments, documents, iconography, paintings etc., of various institutions, is described. Documents and collections, e.g. from donations or purchases, are still being integrated into the archives, and selected material is displayed in temporary exhibits at the Observatory. Modern uses of old material are briefly mentioned.

1. Introduction

During the scientific sessions of the 22$^{\text{th}}$ General Assembly in Manchester (2000) S. Débarbat and J.-P. Cressent, then Curator of the Paris Observatory in charge of the Library, Archives and Historical Instruments, presented a talk on "Alidade". They recalled the beginning of "Alidade" for astronomical archives preserved in France, including archivists and/or curators having responsabilities on such archives, under N. Daliès, former Curator at the Paris Observatory. Unfortunately, a few months later J.-P. Cressent died in January 2001, being replaced by L. Bobis, curator and archivist-paleographer by training, in September 2001.

2. Alidade

Alidade was launched as early as 1995 after an initiative of N. Daliès that began with an enquiry among French institutions to prepare a list

of archival locations in the field of astronomy. With time going on, with an amount of money not sufficient for the total project, and new technical capabilities having appeared, L. Bobis reoriented the work towards every sense of the word *archives*, including not only the archives but also instruments, documents, iconography, paintings, etc. She began with those of the Observatory which were listed on sheets of paper. Such an inventory was published in 1895 in the *Annales de l'Observatoire de Paris, Série Mémoires,* 21, where anyone can find it. The publication was not any more in sufficiently good quality to be directly employed for scanning, before being encoded in EAD XML; it was therefore necessary to retype all the ~120 sheets. This rather long work was made at the Observatory when free time permitted.

Those documents are now completely in order to be put in EAD XML. The work is in progress at a company which specializes in such work, employing the DTD EAD (Encoded Archival Description) developed in the USA and now used by archivists in many countries. In France, it is in use for the national archives. In the list of documents to be included in the Alidade database, there are not only manuscripts such as those from Delisle's portfolio, but also instruments like a portable quadrant from the mid-eighteenth century, medals, statues, photographic plates, paintings, such as a portait of Lacaille who went to the southern hemisphere, drawings, sculptures – that is, everything that constitutes the patrimonial collections.

Rather soon the inventory by Bigourdan, and its main supplements up to now will be on the SDX platform. This inventory is, at present, the main part of the Archives of the Paris Observatory, accumulated by the four Cassinis, Delisle, Lalande and others. Among them are, as examples, the manuscripts on the metric system, the manuscripts of Le Verrier for the search of the body disturbing the motion of the planet Uranus, etc. The inventory of the French Bureau des Longitudes, by Mme Chapront-Touzé (1998), deposited by this Bureau in the Paris Observatory Archives for safety, will be, at the same time, included in the lists.

3. Paris Observatory Library Collections are Open Collections

It is noteworthy that the collections of the Paris Observatory Library are not closed. They are regularly enriched thanks to astronomers and their descendants, bringing new archival sets or any other documents,

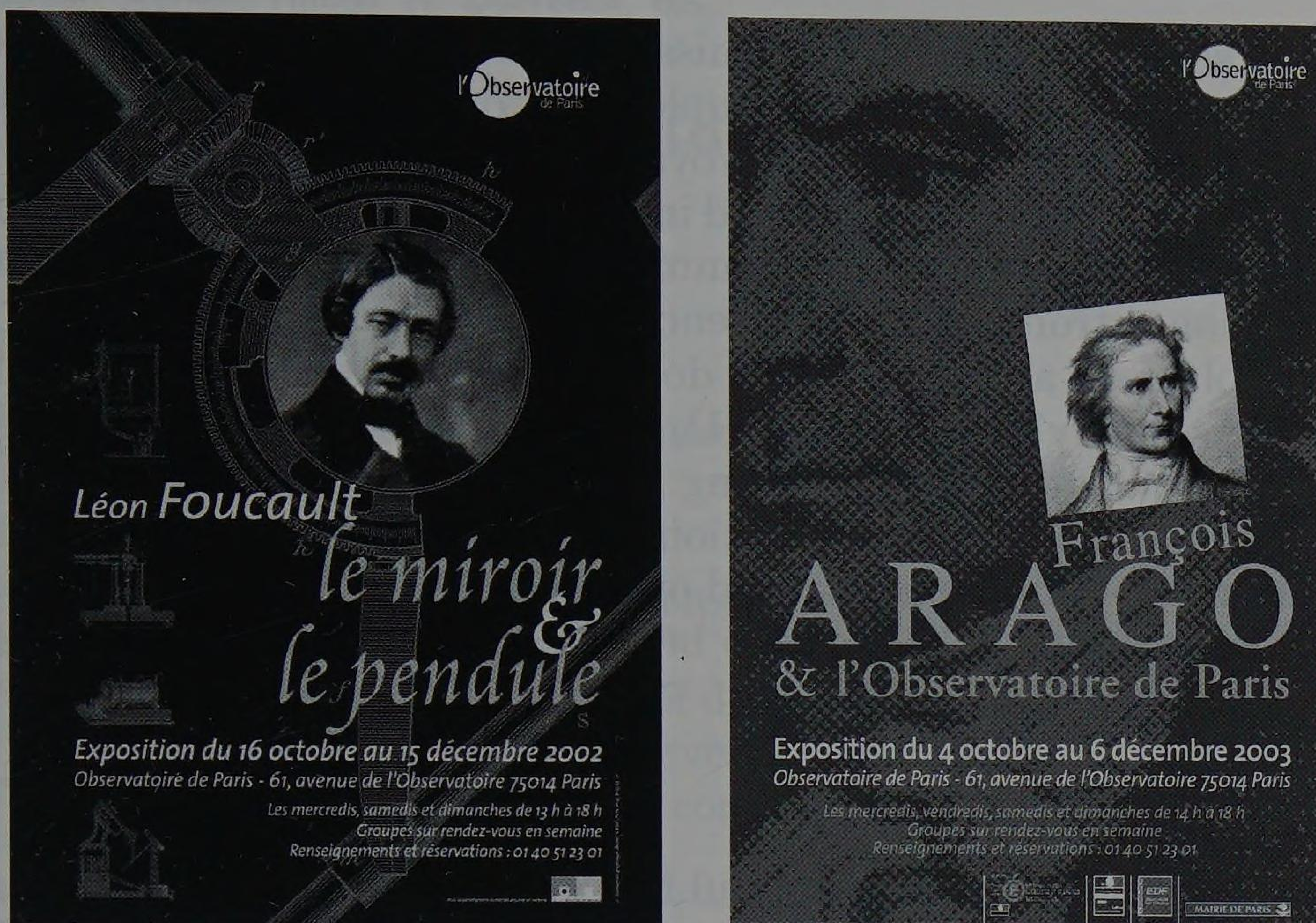

Figure 1. Paris Observatory Library open collections: posters of Foucault and Arago expositions.

objects, portraits, and so on. Such items of patrimonial collections can be shown in part to the public, on the occasion of specific exhibitions installed in the so-called Salle Cassini on the second floor of the building which is now called Bâtiment Perrault after its architect. They allow to relate works of the past to the present activities in the Paris Observatory. In the last three years, exhibitions were made on time (*Temps mesurés – Temps démesurés*, 2001), on Foucault (*Le miroir et le pendule*, 2002), and on Arago (*Arago et l'Observatoire de Paris*, 2003), see Fig. 1. Such exhibitions, as well as previous ones, include many archival documents, objects, instruments from the Paris Observatory as well as from other institutions.

In some cases, the Observatory is fortunate enough to be able to buy some documents; an opportunity arose when the last inheritent of Mouchez (the so-called *Société de sauvetage en mer*) decided to sell what they had from this admiral who had been director of the Paris Observatory between 1878 and 1892. At this auction, the Observatory bought all manuscripts of astronomical interest. But, in some cases, parts of the patrimonial astronomical properties disappear under peculiar circumstances.

On several occasions, Commission 41 has called attention to the value of such collections. For example, the work carried out by J. Lieske to check the ephemerides of the Voyagers made use of the old observations of the eclipses of Io, preserved in the Paris Observatory collections. Other examples were given, at Commission 41, in Manchester (UK) and in the Asian astronomical Conference held in Cheong-ju (Korea).

Resolutions are passed, but do we know what happens after the General Assembly? Under the IAU, it could perhaps be useful to send a circular letter to all the adhering bodies of the IAU asking them to undertake some actions at the national level to ensure that all scientific institutions, in our case in the field of astronomy, are aware of the value of their patrimonial collections to be introduced in their inventories.

4. The Future

Alidade is intended for being useful for astronomy as a field of research in which ancient observations are still of interest even after centuries; proofs were given during the special sessions organised by Commission 41, and once more during the 23$^{\text{th}}$ General Assembly (Sydney 2003). Alidade will be also of interest for the history of astronomy as a subject of research and a subject to teach the students about the evolution of a specific field. It would serve to give better value and consideration to the patrimonial collections comprising all what is related to astronomy, but what will happen in the future in the case of the present time, when so much communication occurs by telephone calls and e-mails?

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Documents Related to Astronomy in German Archives

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Abstract

A short account of holdings of documents related to astronomy in German archives is given. Several online and printed inventories are indicated. The appendix contains a list of selected collections.

1. Overview of Holdings

Astronomical documents can be found in a very large number of German archives. Large collections are e.g. that of the Berlin Academy of Sciences (holding papers from the Berlin and Potsdam observatories, papers of Auwers, Bessel, Bode, Encke and others, as well as papers concerning astronomy at the Berlin Academy), of the Göttingen University Library (keeping papers from the Göttingen Observatory as well as papers of Gauß, Schwarzschild and others), and of the Deutsches Museum at Munich (owning papers of the Munich instrument makers Fraunhofer, Reichenbach, Steinheil and Utzschneider, as well as of some astronomers).

Many observatories keep their files in their libraries or at other places (e.g. Bonn, Hamburg and Munich; also the European Southern Observatory at its headquarter in Garching near Munich – see Blaauw 1992), but the access is mostly difficult. It is not easy to convince institutions to give their papers to professional archives. In the case of Leipzig the files are in the University Library because the observatory does not longer exist.

Papers of astronomers are kept in many different archives and libraries, e.g. that of Max Wolf are stored in the Heidelberg University Library, that of H.C. Schumacher – the founder of *Astronomische Nachrichten* – in the State Library at Berlin. Letters written by

astronomers can also be found among the papers of mathematicians, physicists and scholars from other fields, as well as in autograph collections. One of the largest autograph collection of the world was that of Ludwig Darmstädter kept at Berlin State Library; unfortunately, many items were lost during World War II. Of some importance for biographical information are also the archives of political parties and organization, e.g. the NSDAP files in the *Bundesarchiv* (Federal Archives) at Berlin (taken over from the former Berlin Document Center maintained by the USA at Berlin). For examples of the different fate of papers of German astronomers and on their preservation see Dick (1998).

There are also numerous administrative papers related to astronomy in state archives. The largest collection is kept at the *Geheimes Staatsarchiv Preußischer Kulturbesitz* at Berlin (files from Prussian ministries concerning observatories of Berlin, Kiel, Königsberg, Strassburg and other places).

Medieval manuscripts (Latin and Arab, many non-European) can be found in large and well-known archives as well as in monasteries and other institutions (e.g. at Gotha, see Schwarz et al. 1998). These will not be considered here.

Some years ago the *Astronomische Gesellschaft* (AG), a professional astronomical society founded in 1863, decided to establish its own archives with the help of the Archives of the Berlin Academy of Sciences. These archives will contain the papers of the Astronomische Gesellschaft of the latest decades. Older papers may be found mainly at three places: (1) Leipzig University Archive (from the first decades of the AG, see Münzel 1993), (2) Bonn University Observatory (mainly from the time of Eduard Schönfeld as secretary, ca. 1875–1891), and (3) Archives of the Berlin/Brandenburg Academy of Sciences at Berlin, among the papers of Babelsberg Observatory (especially from the time of Paul Guthnick as secretary, ca. 1924–1933).

Papers related to the IAU can also be found in some archives, e.g. in the Berlin-Brandenburg Academy Archives (among papers of Babelsberg observatory) and in the Bundesarchiv at Berlin (files of German ministries from the Third Reich).

2. Inventories

Unfortunately, the situation with (central) registers of astronomical papers in Germany is rather bad. The book by Ernst Zinner (1925) is, so far, the only general inventory of astronomical papers in Germany.

It covers only the period before 1850, is not complete and is outdated due to World War II losses and other circumstances. An inventory by Diedrich Wattenberg (1974) covers only East Germany and lists only letters. It is incomplete and contains some errors, but is nevertheless very useful.

Astronomers' papers may also be found among inventories of general interest. Personal papers by astronomers in former West Germany may be found with the help of the general inventories by Denecke & Brandis (1981 – holdings of libraries) and by Mommsen (1984 – holdings of archives). For the former East Germany there is only an inventory of holdings in libraries (Anonymous 1959–1971). The State Library at Berlin maintains a Central Register of Autographs (mainly letters), which is helpful also for history of astronomy studies. However, it covers only selected archives in West Germany. Recently this central register started to publish its index files in electronic form (project *Kalliope* – Verbundinformationssystem Nachlässe und Autographen). The State Library coordinates also the project *MALVINE* (Manuscripts and letters via Integrated Networks in Europe, see Fig. 1). The Central Register replies to written requests and may also be used personally on appointment. The Bundesarchiv maintains a database of personal papers (*Zentrale Datenbank Nachlässe*). Holdings of German archives related to astronomy may also be found in the *International Catalog of Sources for History of Physics and Allied Sciences.*

A growing amount of information is available through the World Wide Web, not only via the central databases mentioned above, but also from individual archives. For an (incomplete) list of links to the central inventories and to individual archives in Germany (and in the world), we refer to the History of Astronomy Archives website[1]. However, in comparison with American archives the information available from German archives through the Internet is rather sparse. I do not know of any complete inventory available electronically from a German archive (at least not for any holdings related to astronomy).

Professional archives keep card files and inventories of their holdings, some of which are rather detailed; these are available for visitors, but excerpts are also sent by letter on request.

Some special inventories have been published, e.g. recently a register of astronomical papers in the Gotha Research Library (Schwarz et al. 1998) and a preliminary list of Gottfried Kirch's papers (Herbst

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[1] `http://www.astrohist.org/hist_astr/ha_arch.html`

715	Argasilam	Bedeutung der Zeichen	l	'Bn 3124. 209'-211'		XV.
716	F. W. Argelander	Sternkunde	d	Zür Stern		1830 ±
717	"	Über veränderliche Sterne		Ber Stern	1850	1850
718	"	8 Briefe		Ber Damm J. 1852	1837/72.	1837/72.
719	"	6 Briefe		Heid. Stern	1839/45	1839/45
720	"	27 an Encke		Ber Stern		XIX
721	"	3 an Gauss		Gött. Gauss 95	1846/53.	1846/53
722	"	14 an A. v. Humboldt		Ber Stern	1850	1850
723	"	an J. J. v. Littrow		Bern S. N. G.		XIX
724	"	9 an Nell		Heid Stern	1852/54.	1852/54
725	"	1 an Prinz Friedr. Wilh. v. Preußen		Ber Ant.	1835	1835
726	"	an A. Repsold		Ham Ar A IV & 1	1830	1830
727	"	44 an H. C. Schumacher		Ber S. Schu		

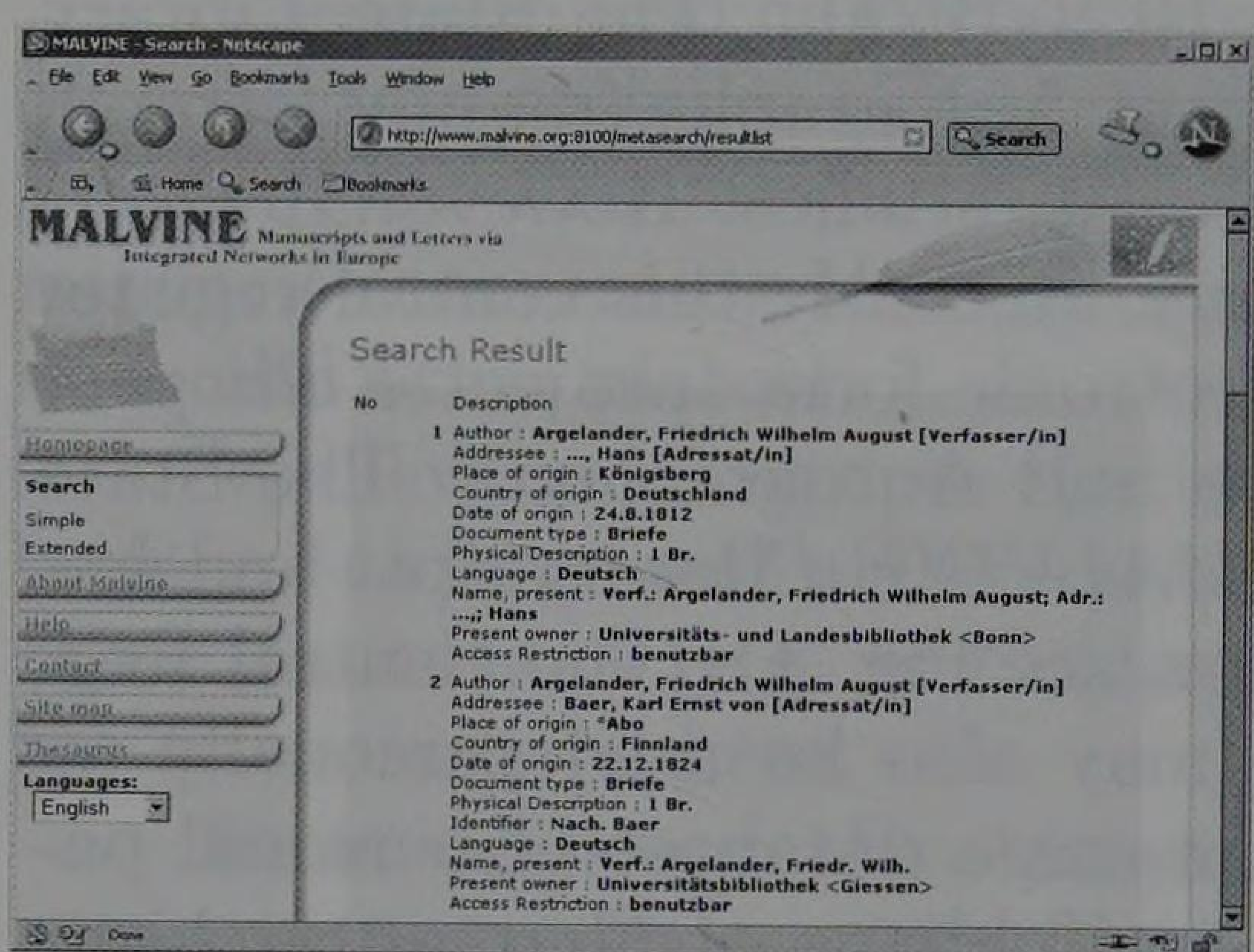

Figure 1. Entries for F.W.A. Argelander. *Top*: in Zinner (1925). Note that Zinner's book was printed directly from the manuscript written by his wife. *Left*: in the Kalliope database from a search through MALVINE.

1999). A nearly complete inventory of letters written by Gauß was compiled by Merzbach (1974). Letters to and from Wilhelm Olbers as well as Franz Xaver von Zach were listed in books by Wattenberg (1994) and by Wattenberg & Brosche (1993). Inventories of Johann Heinrich Lambert's and Michael Maestlin's papers and letters were compiled by Steck (1970, 1977) and Betsch (2002). For short accounts of personal papers of other astronomers see Dick (1993 – Friedrich Wilhelm Argelander), Dick (1995 – Wilhelm Foerster), Dick (2000 – Karl Friedrich Zöllner), Folkerts (1993 – Johannes Praetorius), Klauss (1986 – Friedrich Wilhelm Bessel), List (1961 – Johannes Kepler and Tycho Brahe), Schaldach (1994 – Ernst Zinner), Strumpf and Schwarz (1996 – Peter Andreas Hansen), and Zenkert (1975 – Bruno H. Bürgel). An inventory of the correspondence of Paul Guthnick with Soviet astronomers was published by Dick (1987). Complete inventories of the papers of Johannes Kepler (in the framework of the edition of his complete works, see Kothmann 1996), Gottfried Kirch, Heinrich Christian Schumacher and Wilhelm Foerster are in preparation. Useful hints to archives may also be found in the appendices to research papers and books; a good

example is the book by Litten (1992) on astronomy in Bavaria who used and listed a large number of archival holdings on the subject.

3. Access to Archives

The access to German archives is relatively easy. The visitor has to fill out a short application form and will usually get immediate access to the holdings. However, it is recommended to write to the archives in advance, especially in the case of state archives. The space in the reading rooms of the state archives is limited, and sometimes the files have to be prepared in advance. In some cases one has to wait three or more weeks to get a working place in the reading room. In manuscript reading rooms of university libraries or in smaller archives there is usually enough space for visitors, and the files may be retrieved very quickly. It is also possible to receive copies on written request. However, a personal visit usually yields more complete information.

Appendix: Selected collections

Berlin: Archiv der Berlin-Brandenburgischen Akademie der Wissenschaften
Auwers, Arthur (1838–1915)
Bessel, Friedrich Wilhelm (1784–1846)
Bode, Johann Elert (1747–1826)
Bottlinger, Kurt Felix (1888–1934)
Encke, Johann Franz (1791–1865)
Foerster, Wilhelm (1832–1921)
Grotrian, Walter (1890–1954)
Guthnick, Paul (1879–1947)
Kienle, Hans (1895–1975)
Ideler, Christian Ludwig (1766–1846)
Kirch, Gottfried (1639–1710)
Kirch, Maria Margaretha (1670–1720)
Kirch, Christfried (1694–1740)
Knorre, Viktor (1840–1919)
Lambert, Johann Heinrich (1728–1777)
Miethe, Adolf (1862–1927)
Schmidt, J.F. Julius (1825–1884)
Berlin/Babelsberg Observatory
Astrophysikalisches Observatorium Potsdam

Venusdurchgänge 1874/1882
Geschichte des Fixsternhimmels
Berlin Academy of Sciences (including astronomy)
Reference: Battré & Herrmann (1970); Baumgart (1977); Klauss (1986) [for Bessel]; Steck (1970, 1977) [for Lambert]; Wattenberg (1974)

Berlin: Staatsbibliothek zu Berlin, Handschriftenabteilung
Schumacher, Heinrich Christian (1780–1850)
Autographensammlung (collection of autographs) Darmstädter
Many single autographs

Berlin: Staatsbibliothek zu Berlin, Handschriftenabteilung, Zentralkartei der Autographen (Central register of autographs)
Projects: Kalliope (Verbundinformationssystem Nachlässe und Autographen); MALVINE (Manuscripts and letters via Integrated Networks in Europe)

Düsseldorf: Landes- und Stadtbibliothek
Benzenberg, Johann Friedrich (1777–1846)

Gotha: Forschungsbibliothek
Papers related to the Gotha observatories and astronomers von Zach, F.X., Ernst II., von Lindenau, B.A., Encke, J.F., Hansen, P.A., Gusev, M.M., Becker, E., Harzer, P., Anding, E.
Reference: Schwarz et al. (1998)

Göttingen: Staats- und Universitätsbibliothek Göttingen, Abteilung Handschriften und seltene Drucke
Finlay-Freundlich, Erwin (1885–1964)
Gauß, Karl Friedrich (1777–1855)
Hartmann, Johannes (1865–1936)
Hirsch, Friedrich (1890–1964)
Klinkerfues, Wilhelm (1827–1884)
Lichtenberg, Georg Christoph (1742–1799)
Mädler, Johann Heinrich (1794–1874)
Mayer, Johann Tobias (1752–1830)
Mayer, Tobias (1723–1762)
Olbers, Heinrich Wilhelm Matthias (1758–1840)
Schur, Wilhelm (1846–1901)
Schwarzschild, Karl (1873–1916)

Struve, Friedrich Georg Wilhelm von (1793–1864)
Wolfers, Jakob Philipp (1803–1878)
Göttingen Observatory
Reference: Merzbach (1984) [for Gauß]

Hamburg: Staatsarchiv
Hansen, Peter Andreas (1795–1874)
Schumacher, Heinrich Christian (1780–1850)
Repsold family
Reference: Strumpf & Schwarz (1996) [for Hansen]

Heidelberg: Universitätsarchiv
Wolf, Max (1863–1932)

Leipzig: Universitätsarchiv
Bruns, Heinrich (1848–1919)
Astronomische Gesellschaft
Leipzig Observatory
Reference: Münzel (1993)

München (Munich): Deutsches Museum, Archiv
Boda, Karl (1889–1942)
Drobisch, Moritz Wilhelm (1802–1896)
Fauth, Philipp (1867–1941)
Fraunhofer, Joseph von (1787–1826)
Hartner, Willy (1905–1981)
Hartwig, Ernst (1851-1923)
Kienle, Hans (1895–1975)
Reichenbach, Georg von (1771–1826)
Schwerd, Friedrich (1792–1871)
Seidel, Ludwig Philipp von (1821–1896)
Steinheil, Carl August (1801–1870)
Utzschneider, Joseph von (1763–1840)
Wilkens, Alexander (1881–1968)
Many autographs
Reference: Füßl & Mayring (1994)

Münster: Universitätsarchiv
Hellerich, Johannes (1888–1963)

Potsdam: URANIA-Planetarium mit Bürgel-Gedenkstätte
Bürgel, Bruno H. (1875–1948)
Reference: Zenkert (1975)

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Foerster, Friedrich Wilhelm Foerster und Karl Foerster. Milow, p. 100.

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ASTRONOMICAL HERITAGES: Astronomical Archives and Historic Transits of Venus
Journal of Astronomical Data, Vol. 10, 7, 2004
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The Sound Archive of Archenhold Observatory – An Overview

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Abstract

A short overview of the sound archive of the Archenhold Observatory in Berlin-Treptow is given. Among the more than 250 recordings, there are many semi-popular lectures of astronomers from the Berlin area, Jena, and visitors from abroad, spanning the years 1966–1990.

1. Archenhold Observatory

In 2002, Archenhold Observatory and its Zeiss-Großplanetarium were integrated into the Deutsche Technikmuseum Berlin (German Museum of Technics, Berlin, a foundation of public law). By this, manpower became available to systematically catalogue the extensive archival documents that belong to the Observatory. The archive is still in a developing state, and the complete register of all documents which are important with respect to the history of the Observatory (written material, pictures, sound and video recordings) will certainly take quite some time.

2. The Collection of Sound Documents

The notable collection of sound documents forms an important part of the archive. When systematic recordings were introduced, the idea was first to document the lectures of well-known guest speakers, and thus to avoid a neglect that had occurred in previous years. Later, also other events were documented by sound recordings, e.g. sessions of the

working group for the history of astronomy which were outstanding because of special visitors or topics, or speeches given at the inauguration of the Einstein memorial tablet at the entrance of the great hall (Einstein hall) of the Observatory. Occasionally, interviews of visitors were recorded, either because of topical reasons, or because they were used as audio material in the exhibitions. The sound archive also contains radio recordings in which members of the Observatory took part, and recitations of historical texts of famous astronomers by artists.

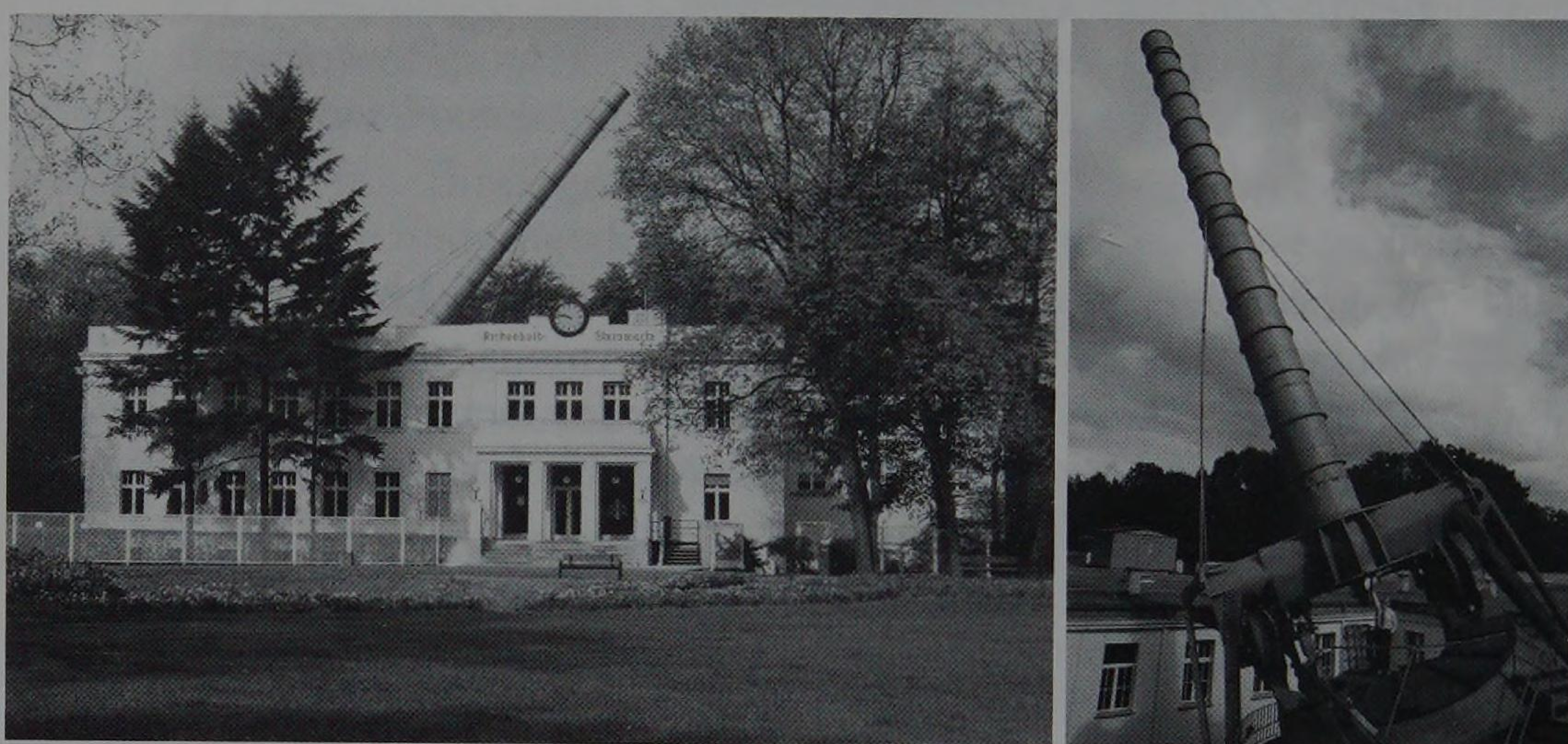

Figure 1. Archenhold-Sternwarte, Berlin-Treptow.

In October 1987, when the Zeiss-Großplanetarium was opened as an operational unit of the Archenhold Observatory, many activities were shifted to the new place. Among these were also the talks of out-of-town lecturers, which were often recorded. Unfortunately, the documentation, which was carried out very carefully in the beginning, was not continued in a systematic way. Reasons for this were: (a) the small staff was very busy with the putting into operation of the new planetarium whose planning stage started in 1985, and (b) the drastic decline in number of staff members after 1990.

At the moment, first lists of sound recordings are available, which are certainly not yet complete. It is foreseen to produce digital versions of the most important recordings, in order to counteract the decay of quality of the magnetic tapes.

We do not intend to document in this place all registered recordings with precise date, duration and topic, since we may assume that the information is only a preliminary one. It is possible that more sound

material will be recovered. In addition, the contents are only documented by the existing cards, not by actually listening to the tapes. In total, about 250 documents are available, spanning the time between 1966 and 1990. In order to give a fairly representative overview of the collection, a selection of recordings of important lectures with names of the speakers and their topics is listed in Table 1. In this way, we offer a possibility for interested persons to inquire about more details by contacting the Archenhold-Sternwarte, Alt-Treptow 1, D-12435 Berlin (Tel. [49] (030) 5348080, Fax [49] (030) 5348083, info@astw.de).

Table 1: Sound recordings at Archenhold Observatory.

Lecturer	Year	Title
H. Bernhard	1979	20 Jahre Astronomie-Unterricht in der DDR
H.H. v. Borszeskowski, R. Wahsner	1978	Schwarze Löcher – Physikalische und philosophische Probleme
K.-R. Biermann	1974	Bessels Projekt einer populären Astronomie in seinem Briefwechsel mit A. v. Humboldt
J. Dorschner	1975	Kosmische Zivilisationen?
J. Dorschner	1976	Moderne Vorstellungen über die Entstehung des Planetensystems
H.W. Duerbeck, W. Seitter	1978	Die Neuen Sterne in Vergangenheit und Gegenwart
H. W. Duerbeck, W. Seitter	1980	Neue Sterne in neuer Sicht
H. W. Duerbeck	1981	Das Bild der Milchstraße 1780–1980
H.-J. Felber	1976	Zeitrechnung und Kulturgeschichte
H.-J. Felber	1977	Gauß und die Osterrechnung
H.-J. Fischer, H. Pfau	1975	10 Jahre Programm Interkosmos
E.G. Forbes	1974	Navigationswissenschaft im 18. Jahrhundert
Ch. Friedemann	1975	Frühphasen der Sternentwicklung
Ch. Friedemann	1976	Kosmische Einflüsse auf die Erde und das Leben

Lecturer	Year	Title
K. Fritze	1977	Schwarze Löcher im Weltall?
O. Gingerich	1977	Copernicus, Tycho Brahe und die Neue Astronomie
M. Greßmann	1979	Die Kleinen Planeten
A. Griese	1975	Die Richtung der Zeit – philosophische Aspekte und ihre physikalische Begründung
J. Hamel	1972	Über verschiedene Arten von Gesetzen
F. Herneck	1977	Nicolaus Copernicus und die Typologie der Gelehrten
F. Herneck	1975	Planck und Einstein. Zwei Physiker, zwei Welten, ein Weltbild
F. Herneck	1977	Einstein und die Sterne
F. Herneck	1979	Albert Einstein – Ein Leben für Wahrheit, Menschlichkeit und Frieden
D.B. Herrmann	1971	Astronomie und Weltraumforschung in ihren technischen und wissenschaftlichen Beziehungen
D.B. Herrmann	1972	Das Gesetz der Sternwartengründungen
D.B. Herrmann	1974	Laudatio auf Diedrich Wattenberg
D.B. Herrmann	1977	Zur Geschichte des Entwicklungsgedankens in der Astronomie
D.B. Herrmann	1979	Einstein, Archenhold und die Popularisierung der Naturwissenschaften
D.B. Herrmann	1980	Ziolkowski im Spiegel westeuropäischer Raumfahrtliteratur
H. Hess	1978	Die Geschichte der Berliner Urania
G. Hoppe	1983	Meteorite – Zufallsboten aus dem All
F.W. Jäger	1971	Aspekte der solar-terrestrischen Forschung
H. Kautzleben	1976	Erderkundung aus dem Weltraum
R. Kippenhahn	1983	Zur jüngeren Geschichte der Sternevolutionsforschung
F. Krause	1978	Das Rätsel der Sonnenflecken
H. Künzel	1975	Zur Magnetfeldmessung in den Sonnenflecken
L. Kühne	1976	Physikalische Bedingungen und chemische Zusammensetzung der Planetenatmosphären

Lecturer	Year	Title
H. Lambrecht	1971	Die Verantwortung des Wissenschaftlers
H. Letsch	1974	Die Bedeutung der Zeiss-Planetarien für die Popularisierung der Astronomie
D.-E. Liebscher	1978	Geometrie und Kosmos
D.-E. Liebscher	1979	Einsteins spezielle Relativitätstheorie
D.-E. Liebscher	1979	Geometrie und spezielle Relativitätstheorie
D.-E. Liebscher	1979	Einsteins Probleme heute
K. Lindner	1979	Ergebnisse u. Aufgaben der Amateurastronomie
K. Mann	1980	Vladimir Mandl und das Weltraumrecht
S. Marx	1983	Tendenzen beim Bau großer Teleskope
H. Mielke	1977	Raumfahrt für die Erde
D. Möhlmann	1983	Die Entstehung unseres Sonnensystems
O. Oburka	1976	Volkssternwarten und Forschungssternwarten in der CSSR
H. Oleak	1975	Die kosmogonischen Forschungen und Hypothesen von W.A. Ambarzumjan
H. Oleak	1977	Kosmologie aus der Sicht der beobachtenden Astronomie
H. Oleak	1979	Die Zusammenarbeit zwischen der DDR und der UdSSR auf dem Gebiet der extragalaktischen Forschung
M. Reichstein	1976	Planetenoberflächen – Grundzüge der Gestaltung und Evolutionsmerkmale
N. Richter	1971	Neue Forschungsergebnisse aus der Welt der Galaxien
N. Richter	1974	Aus der Geschichte des Karl-Schwarzschild-Observatoriums
G. Richter	1976	Moderne Tendenzen beim Bau großer Radioteleskope
G. Ruben	1979	Die astronomische Forschung am Zentral institut für Astrophysik der AdW
K.-H. Schmidt	1971	Interstellare und intergalaktische Materie im Lichte der Kosmogonie
K.-H. Schmidt	1975	Astrophysikalische Ergebnisse extraterrestrischer Forschungen

Lecturer	Year	Title
K.-H. Schmidt	1976	Wie altern Galaxien?
K.-H. Schmidt	1983	Neues aus der Welt der Galaxien
K.-H. Schmidt	1987	Tendenzen der Zukunft der Astronomie
W. Seitter	1989	Bauplan des Universums
J. Staude	1979	Sonnenforschungen am Einstein-Turm in Potsdam
K.-G. Steinert	1976	Die Bestimmung präziser Sternpositionen und deren Bedeutung für die Astronomie
G. Strohmeier	1981	Gotische Kunst und arabische Astrologie
H.-J. Treder	1971	Das Olberssche Paradoxon und seine Bedeutung für die Kosmologie
H.-J. Treder	1974	Die kosmologischen Ideen im Lehrgedicht des Lukrez, der "Göttlichen Komödie" von Dante, dem Poem "Heureka" von Poe und die heutigen mathematischen Weltmodelle
H.-J. Treder	1977	Irdische und solare Neutrinos
H.-J. Treder	1979	Albert Einstein – Um- und Neugestalter der Physik
H.-J. Treder	1981	Energie im Makrokosmos
R. Wahsner	1977	Philosophische Aspekte der Entwicklung im Kosmos
D. Wattenberg	1971	Zur Ikonographie Johannes Keplers
D. Wattenberg	1973	Wie ich zur Astronomiegeschichte gekommen bin
D. Wattenberg	1975	Frauen am Fernrohr – Frauengestalten am Firmament
D. Wattenberg	1976	Astronomische Motive in der Musik
J. Wempe	1971	Die Hyaden als Basis der kosmischen Entfernungsskala
J. Wempe	1974	Die Beziehungen zwischen Karl Schwarzschild und Ejnar Hertzsprung
K.-F. Wessel	1975	Vorurteile in der wissenschaftlichen Forschung
A. Zenkert	1974	Zur Geschichte der populären Astronomie in Potsdam
H. Zimmermann	1978	Gas und Staub – Rohstoff der Sterne

ASTRONOMICAL HERITAGES: Astronomical Archives and Historic Transits of Venus
Journal of Astronomical Data, Vol. 10, 7, 2004
Christiaan Sterken, Hilmar W. Duerbeck, eds.

The Crawford Collection at the Royal Observatory Edinburgh

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ABSTRACT

The Crawford Collection of books and manuscripts at the Royal Observatory Edinburgh contains the first editions of nearly every book important in the history of astronomy and related fields. It is especially rich in early literature on comets (a collection of over 1000 tracts, described as unrivalled anywhere, including 19th century observations) and many treatises on astrology.

1. Introduction

The Crawford Collection of books and manuscripts at the Royal Observatory Edinburgh, one of the most extensive and valuable astronomical libraries in the world, was the gift of James Ludovic Lindsay, 26th Earl of Crawford (formerly Lord Lindsay) in 1888. Lindsay was a distinguished amateur astronomer who set up a private observatory on the family's country estate at Dun Echt, Aberdeenshire, in the north of Scotland, in 1872. He appointed David Gill (later Sir David, Her Majesty's Astronomer at the Royal Observatory at the Cape of Good Hope) as Director, with whose help he furnished it with a set of astronomical instruments from the best opticians in Europe. Inspired by his father, the 25th Earl of Crawford, a leading bibliophile and book collector, Lord Lindsay also assembled at Dun Echt a magnificent library of astronomical books and manuscripts.

Dun Echt Observatory flourished for almost twenty years but, in 1888, on learning that Scotland's modest Royal Observatory in the city of Edinburgh was under threat of closure, Lindsay now 26th Earl of Crawford, saved the day by magnanimously donating the entire contents of his observatory, including its by now priceless library, to the

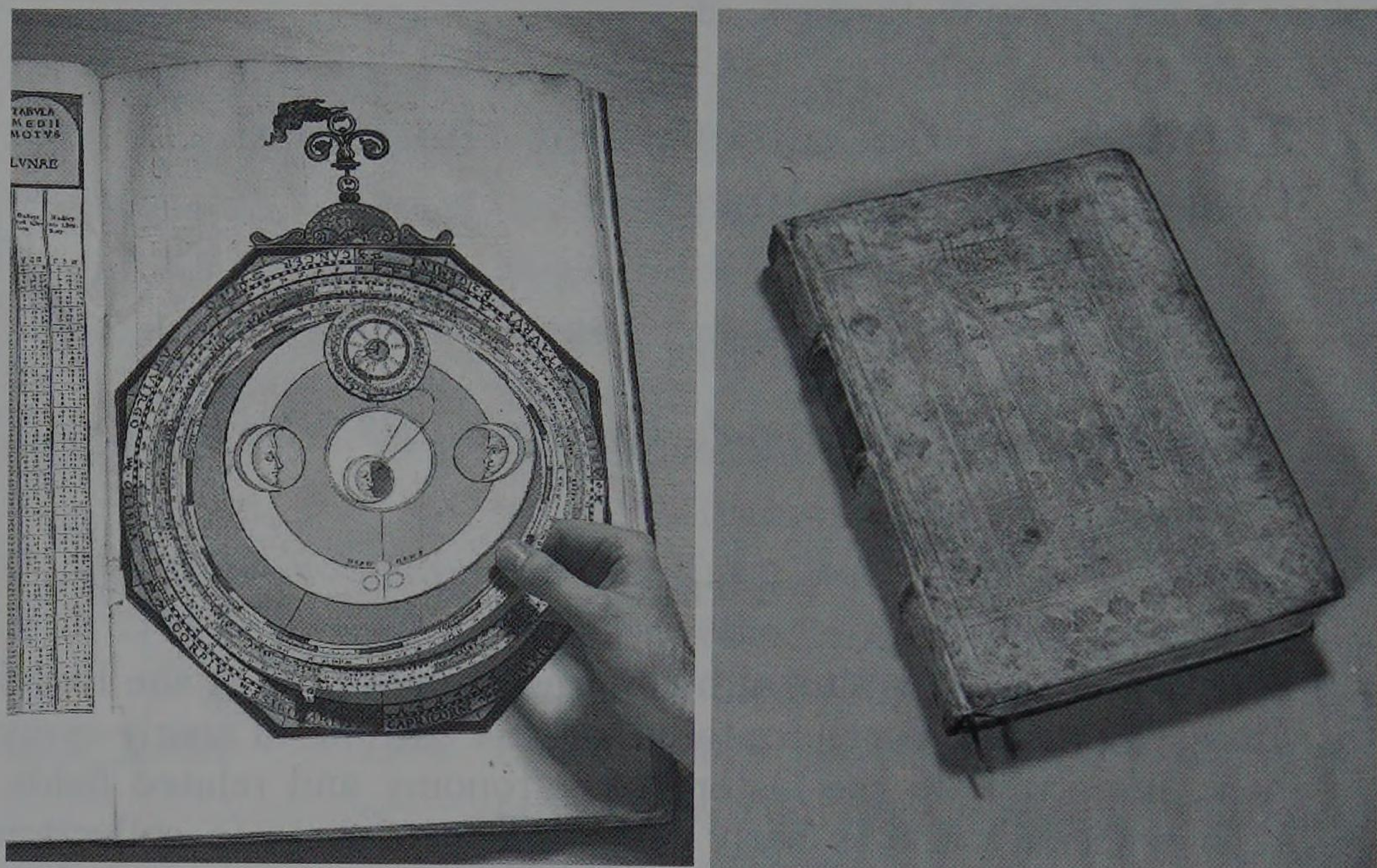


Figure 1. *Left:* Apianus (1495–1552), *Astronomicum Caesareum. Right:* Nicholas Copernicus (1473–1543), front cover of *De Revolutionibus Orbium Coelestium.*

nation. The whole was housed in a new Royal Observatory building, completed in 1896, which remains the home of Edinburgh astronomy with Edinburgh University's IfA (Institute for Astronomy) and, more recently, the UKATC (United Kingdom Astronomy Technology Centre).

The Crawford family's principal residence was at Haigh Hall near Wigan in Lancashire, where the 25th Earl housed his great library. This, however, he felt was lacking in scientific books, and in 1870 he invited his astronomer son to make good the deficiency. The son was only too happy to do this. In collecting his specialist library, Lord Lindsay used as his guide Otto Struve's catalogue of the famous library of the Imperial Observatory at St. Petersburg (Pulkova), at that time the greatest scientific library anywhere. He received the best possible counsel in this from Pulkova's Director, Otto Struve, from whom he also took close advice on equipping his observatory. Some books were first transferred from Haigh Hall to Dun Echt.

A notable acquisition at an early stage, and the nucleus of the collection, was the entire library of Charles Babbage, the computer pioneer and former Lucasian Professor of Mathematics at Cambridge,

which came up for auction after his death in 1871. This collection alone contained over 2500 items on astronomy, mathematics and other sciences. Another valuable collection of books and manuscripts from the library of the French mathematician Michel Chasles, who died the previous year, was acquired in 1881. Rare books were systematically purchased at sales in London, and from Germany and elsewhere in Europe. Within ten years, Lord Lindsay – who on the death of his father in 1881 became Lord Crawford – had amassed a library of 11,000 books, forming one of the great scientific collections of the world.

2. The Most Precious Items in the Collection

H. A. Brück described the most precious items in the Collection in his *Story of Astronomy in Edinburgh*:

> The library contains the first editions of nearly every book important in the history of astronomy and related fields. It is especially rich in early literature on comets [a collection of over 1000 tracts, described as unrivalled anywhere, including 19th century observations in which Lord Crawford had a special interest] and there are many treatises on astrology.
>
> The pre-Copernican period of astronomy is represented by the earliest printed edition of 1478 of Sacrobosco's (John Holywood's) *Sphaera Mundi*; by a near perfect copy of Apianus' *Astronomicum Caesareum* of 1540, with working planispheres; and by many other volumes.
>
> There is a beautiful copy of Copernicus' *De Revolutionibus Orbium Coelestium* of 1543 with annotations by Erasmus Reinhold who was Professor of Astronomy in Martin Luther's University at Wittenberg from 1536 to 1553.
>
> There is a copy of Reinhold's *Tabulae Prutenicae* of the motions of celestial bodies calculated on the basis of Copernicus' *De Revolutionibus.* The Collection also contains a copy of the first edition of 1627 of Kepler's *Tabulae Rudolphinae*, which superseded Reinhold's and remained the standard astronomical tables for more than a century.
>
> Amongst the many Kepleriana in the Collection mention may be made of Kepler's pamphlets on the new star which appeared in 1604, and of his famous book *Harmonice Mundi* which was published in 1619. The Collection's copy holds

within its covers an autograph sheet by Kepler, being part of a contract and specification for a hydraulic engine. There is also a copy of Kepler's *Astronomia Nova*, printed in 1609 and containing Kepler's well-known first two laws of planetary motion which he established from Tycho Brahe's observations of the motion of the planet Mars. Tycho Brahe's own publications are very well represented, starting from his observation of the Nova of 1572 to the description of his instruments in *Astronomiae Instauratae Mechanica* of 1602.

The Collection's many books by Galileo include a fine copy of his *Sidereus Nuncius* of 1610, with his observations of Jupiter's satellites amongst others; a copy of *Istoria e Dimistrationi* of 1613, with his earliest drawings of sunspots; and *Il Saggiatore* of 1623, a well-known piece of his controversial writing.

The Collection's editions of Isaac Newton's *Principia Mathematica* include the first edition of 1687, with an imprimatur by S. Pepys, then President of the Royal Society, and the third edition of 1726 with Newton's portrait by Vanderbank.

Amongst mathematical treatises in the collection are some thirty editions of Euclid. These include the first Latin edition (Venice 1482), the very rare Paris edition of 1516, the first Greek edition (Basle 1533), the first English edition (London 1570) and the first Arabic edition (Rome 1594).

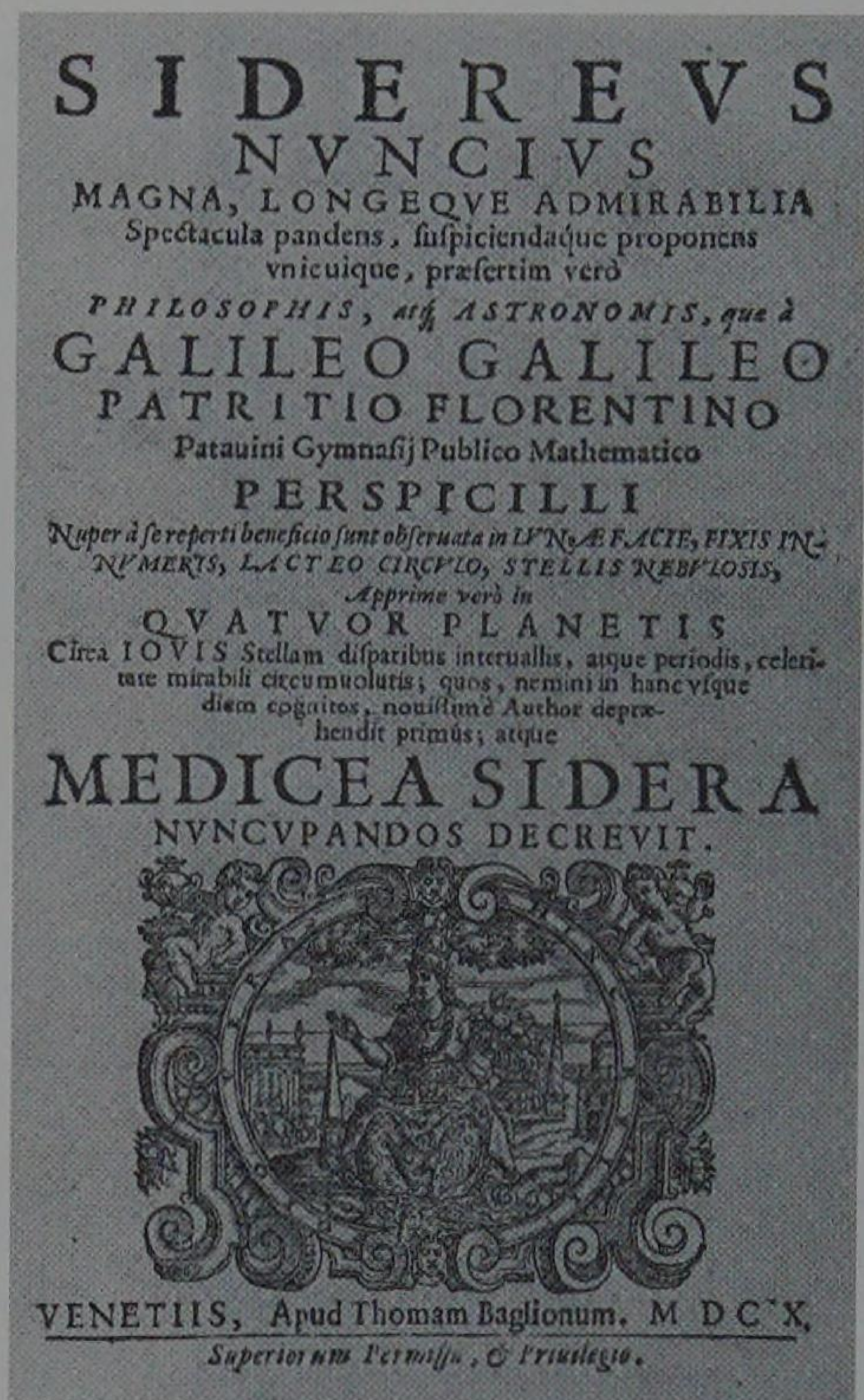
Of particular Scottish interest are the Collection's treatises on logarithms by Baron Napier of Merchiston. They include his announcement of their discovery and his first logarithm table which he published in 1614 under the title *Mirifici Logarithmorum Canonis Descriptio.*

The library at Dun Echt was also up to date in current astronomical literature and publications which also accompanied the Collection to Edinburgh. Included, and worth mentioning, is a set of the ambitious short-lived journal on astrophysics, first named *Urania* but renamed *Copernicus*, which ran for three years (1881–1883), and was financed by Lord Crawford. It was edited by Ralph Copeland and J.L.E. Dreyer and published from Dublin and Göttingen.

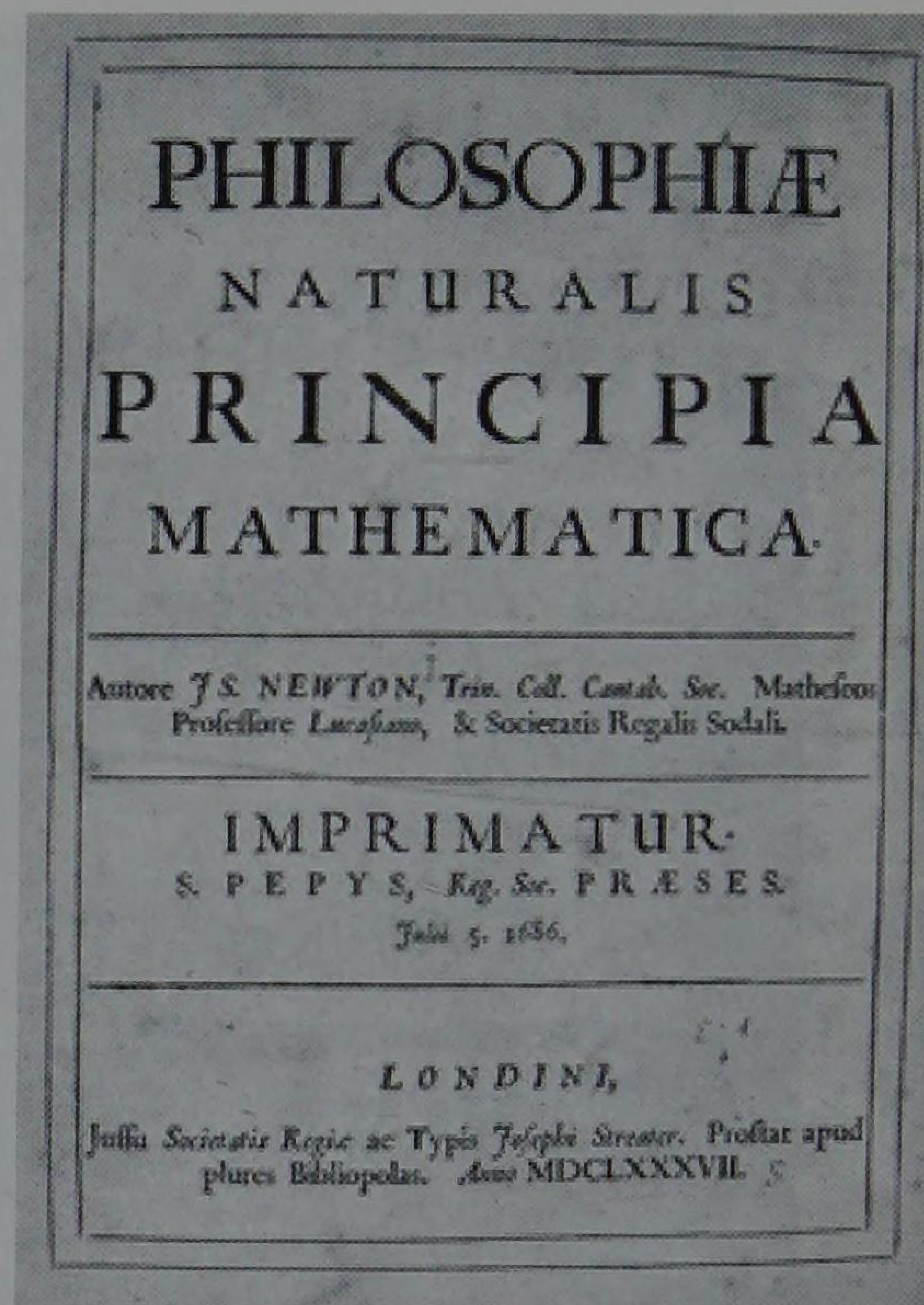
Figure 2. Tycho Brahe (1546–1601), illustration from *Astronomiae Instauratae Mechanica.*

3. Cataloguing the Crawford Library

The task of cataloguing the Crawford library was undertaken by Ralph Copeland, Director of Dun Echt Observatory at the time of its transfer to Edinburgh, who had a deep scholarly knowledge of the Collection as well as being a close personal friend of Lord Crawford. Copeland



SIDEREVS
NVNCIVS
MAGNA, LONGEQVE ADMIRABILIA
Spectacula pandens, suspiciendaque proponens
vnicuique, præsertim verò
PHILOSOPHIS, atq; ASTRONOMIS, quæ à
GALILEO GALILEO
PATRITIO FLORENTINO
Patauini Gymnasij Publico Mathematico
PERSPICILLI
Nuper à se reperti beneficio sunt obseruata in LVNÆ FACIE, FIXIS IN-NVMERIS, LACTEO CIRCVLO, STELLIS NEBVLOSIS,
Apprime verò in
QVATVOR PLANETIS
Circa IOVIS Stellam disparibus interuallis, atque periodis, celeritate mirabili circumuolutis; quos, nemini in hanc vsque diem cognitos, nouissimè Author deprehendit primus; atque
MEDICEA SIDERA
NVNCVPANDOS DECREVIT.
VENETIIS, Apud Thomam Baglionum. M DC X.
Superiorum Permissu, & Priuilegio.



PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.
Autore JS. NEWTON, Trin. Coll. Cantab. Soc. Matheseos Professore Lucasiano, & Societatis Regalis Sodali.
IMPRIMATUR.
S. PEPYS, Reg. Soc. PRÆSES.
Julii 5. 1686.
LONDINI,
Jussu Societatis Regiæ ac Typis Josephi Streater. Prostat apud plures Bibliopolas. Anno MDCLXXXVII.

Figure 3. *Left:* Galileo Galilei (1564–1642), title page of *Sidereus Nuncius*. *Right:* Isaac Newton (1643–1719), title page of *Principia Mathematica* [1st ed.].

became Astronomer Royal for Scotland and Professor at the University of Edinburgh and thus accompanied the instruments and its library to its purposely designed new building. Copeland's Catalogue was published in 1890. Lord Crawford's formal connection with astronomy ceased with the opening of the new Royal Observatory. He devoted his remaining years to extending and cataloguing the glorious library at Haigh Hall which he had inherited from his father. He completed his immense catalogue in 1910 and saw it published before his death in 1913.

The day-to-day working part of the Dun Echt library joined the volumes that already existed at the Royal Observatory, some of which have meantime been preserved for their historical value. The entire Collection (comprising over 8000 items) was indexed and computerised in 1972 by the archivist Mary I Smyth, and re-housed in a special secure Crawford Room at the observatory where it is available to scholars. The

Crawford Room was further extended in 1988 to hold other valuable books.

A history of the Collection, based on an address he gave at the opening of the Crawford Room in 1972, was published by the late Eric Forbes, Professor of History of Science at the University of Edinburgh. An exhibition of some of its treasures, entitled *A Heavenly Library*, was held at the National Museums of Scotland in Edinburgh in 1994, the illustrated catalogue of which is an additional source of scholarly information. As for the future purpose of this priceless collection, we may quote the words of the 28th Earl of Crawford, grandson of the original donor, who said of him:

> "It was fundamental to his point of view that the history of science was an important subject of itself, a subject in which scientists could and should take an interest."

Those interested are welcome to get in touch with the archivist and librarian at the Royal Observatory Edinburgh, Karen Moran.

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ASTRONOMICAL HERITAGES: Astronomical Archives and Historic Transits of Venus
Journal of Astronomical Data, Vol. 10, 7, 2004
Christiaan Sterken, Hilmar W. Duerbeck, eds.

The Japanese Astronomical Archives Project

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ABSTRACT

Due to recent activities of local libraries and museums in Japan for collecting and cataloguing historical books and documents and their increased efforts to publicize such information via Internet services, we are now in a position to have a much easier and better access to the historical resources preserved than in the past. With this background, we started in 2002 a project under governmental support for four years, to make a general inventory of Japanese archives in astronomy and relating disciplines written or published before 1870. Since in pre-modern Japan astronomical knowledge and books were circulated mainly in hand-written form so that they have been apt to be lost in wars and fires, there are good reasons for us to now compile such an inventory through extensive and systematic surveys of both domestic and overseas sources. In April 2003, we published an inventory book of 250 pages, which is intended to be a basis for our survey, including about 4600 titles collected from known source materials. We expect that by March 2006 the number of titles will be increased by 30–35%. This paper briefly introduces the current status of this project and presents the characteristics and problems of Japanese astronomical archives.

1. Introduction

The main goal of our project described here is to prepare a general inventory of the astronomical literature written or published in Japan before 1870. Actually our project is part of a much larger one, and in

order to give readers a better understanding of the aim and perspective of our project, we begin with a short overview of the historical background.

From the beginning of the 17^{th} century through the 1860s, i.e. for about 260 years (the Edo period), Japan was under the rule of the Tokugawa Shogun Family, and a strict policy of seclusion from foreign countries was observed. The only window to the outer world was through narrow trading channels with the Netherlands, China and Korea. Since there was no large-scale turmoil like civil wars and alien invasions during this period, a Japanese original culture could florish in some special fields, although the pace of progress was fairly slow.

In 1868, due to both domestic and overseas pressure, the Shogun government was at last obliged to abandon its ruling and to put it into the hands of a modernized democratic state, under the reign of the Meiji Emperor. This is called the Meiji Restoration. The Shogunate government (the Ancient Samurai Regime) was totally destroyed, and there is apparently no continuity from the Shogunal to the Meiji governments in terms of personnel and organization. Astronomy is no exception either: the Shogunal astronomical office then called *Tenmon-kata*, established in 1684, immediately disappeared after the Restoration.

The first director of the Tokyo Astronomical Observatory (established by the Meiji government in 1888 as a branch institute of the University of Tokyo), Hisashi Terao, who studied western astronomy at Paris Observatory and at La Sorbonne in 1879–1883, had no astronomical background of the Edo period. Japanese astronomy could soon catch up with western standards, at least in the field of classical astronomy, as represented by the discoveries of the Z-term in the polar motion of the Earth's rotation axis by Hisashi Kimura (1902), and the asteroid families by Kiyotsugu Hirayama (1918); both were Terao's early students.

Considering such a rapid modernization of Japan in astronomy, our suspicion was that there should have existed some spiritual and cultural continuity in the astronomy between the Edo period and the post-Edo period. Hence, in an attempt to consolidate the basis for clarifying the nature of astronomy in the Edo period and the possible influence on Japanese modern astronomy from the Ancient Regime time, several years ago, I started compiling an inventory of Japanese astronomy-related books written and published before 1870. Around 2001, a large national research project to study the science and technology of the Edo period was launched with financial support from the Ministry of

Education and Science (see `http://www.ied.co.jp/edomono/`), and we were requested to join it.

2. National Project for Studying Edo Period Science and Technology

Here I simply overview the scope and organization of this big project, following the brochure published by the organizing committee (National Science Museum 2002). For convenience, this project categorized the historical products in science and technology of the Edo period into two groups, books and documents mainly written by scholastic people, and instruments and tools produced by artisans and craftsmen. In the past, the former group used to be studied by researchers at universities and libraries, the latter group by museum curators, with a strong bias toward written and printed materials and little communication between the two groups.

This project aims at intercultural studies connecting the two categorized groups, in a systematic and synthetic way, under the mutual collaboration from different disciplines, such as mathematics, astronomy, medical sciences, natural history, botany and zoology, mining, fine arts, mechanical engineering, western learning, etc. Goals of this project are:

1. compilation of general inventories for cultural and historical assets in each field,
2. construction and diffusion of the resulting databases through electronic means,
3. giving impacts to other disciplines, with fostering young researchers in the field of history of science and technology, and
4. new assessment of the Edo period, regarded obsolete in the past.

For these purposes, the government funded more than 20M dollars for the 2002–2006 period. The project consists of about 60 teams, including about 400 researchers altogether from universities, libraries and museums.

3. The Japanese Astronomical Archives Project

As one of the teams belonging to this project, we launched the studies entitled *Global Survey of Japanese Historical Materials Relating to*

Astronomy Written or Published before the Meiji Era. Our team consists of seven co-investigators, 6 domestic collaborators, three overseas collaborators from Taiwan, Korea and China[1], and the author as principal investigator. We planned to make a thorough survey investigation of historical sources on Japanese astronomy and relating disciplines stored at libraries and museums in China, Korea, Taiwan, USA, France, Britain, Germany, Portugal, Russia, Sweden, etc., in addition to the 47 prefectures of Japan.

The most extensive list ever published on the pre-modern Japanese astronomical literature is that by Watanabe (1987). Although his achievement had an unprecedented value in terms of wide coverage and abundance, it now reveals inevitable limitations, being a one-person work mainly carried out before World War II, and this is one reason why we started the present research. As for the resources written in English, the bibliography of Japanese pre-modern astronomy given in the appendix of Nakayama's (1969) book is still valuable. A major complaint common to the above two catalogues stems from the lack of descriptions of the whereabouts for each book title, which often discourages practical studies. Hence, our intention was that our new catalogue gives good information in which libraries a particular book is kept.

In order to complete our general catalogue of Japanese historical astronomy, we adopted a two-step approach. The first step was to compile an "Inventory Book for Survey (IBS)" by collecting materials from existing bibliographical catalogues. The major source for the preparation of our IBS was *Kokusho Somokuroku* (General Inventory of National Books before 1868) (1963–1973, revised version: 1989–1991), supplemented with some other sources. This catalogue ($8 + 3$ volumes) includes Japanese books in all disciplines written or published before 1868, comprising about 9500 pages, and the total number of books listed is ~840,000, with whereabouts for each book. By carefully scanning all the pages of this catalogue, we picked up about 4600 astronomy-related book titles with assistance by several graduate students and part-time workers. Using Excel (Microsoft) and PageMaker software, we prepared both a printed inventory book of ~250 pages (IBS) and a CD-ROM version which is useful for sorting as well as bibliographic statistics. Our IBS covers also the fields of land-surveying, navigation

[1] Overseas members are Professors Nha Il-Soeng (Korea), Han Yanben (China) and Jochi Shigeru (Taiwan).

図書館・文庫名

略称	図書館・文庫名	有無	種別	都道府県	備考
小樽商大	小樽商科大学		大学	北海道	
伊達開拓記念館	伊達市開拓記念館	3	市立	北海道	
道庁	北海道庁	3	県立	北海道	
函館	函館市立函館図書館	6	市立	北海道	
北学大	北海道教育大学		大学	北海道	
北大	北海道大学		大学	北海道	
北海学園	北海学園大学		大学	北海道	
青森	青森県立図書館	6	県立	青森県	
青森工藤	青森県立図書館工藤文庫	2	県立	青森県	
青森県庁			県立	青森県	
弘前	弘前市立弘前図書館	30	市立	青森県	
岩手	岩手県立図書館	7	県立	岩手県	
岩手大	岩手大学		大学	岩手県	
盛岡公民館	盛岡市中央公民館		市立	岩手県	
斎藤報恩会	斎藤報恩会自然史博物館		私立	宮城県	仙台市
塩釜	塩竈神社	1	私立	宮城県	宮城県塩釜市
仙台市博物館			市立	宮城県	
高鍋町立図書館	高鍋町立高鍋図書館		市立	宮城県	宮城県児湯郡
東北大	東北大学	467	大学	宮城県	
東北大岡本	東北大学岡本文庫	80	大学	宮城県	
東北大狩野	東北大学狩野文庫	557	大学	宮城県	
東北大教養	東北大学教養部		大学	宮城県	
東北大林	東北大学林文庫	241	大学	宮城県	
東北大藤原	東北大学藤原文庫		大学	宮城県	
宮城	宮城県図書館	8	県立	宮城県	

Figure 1. A sample page of the survey library list.

and some other sciences in addition to astronomy, because there was no clear distinction of these disciplines in the Edo era.

The second step was to make surveys of unknown books and documents in candidate libraries, based upon the IBS. When we mention "unknown", its meaning is twofold: the first is the discovery of an unknown title, which is of course most valuable. The second is to find out a particular known title in a library which has never been explored before and thus IBS does not include the name of the library. It is also important to confirm whether or not the books described in IBS are still actually stored in those corresponding libraries, since many libraries more or less suffered from World War II damage.

For our survey purposes, we made a list of about 770 libraries all over Japan. Figure 1 shows part of a page from the library list. The first column to the sixth, respectively, represent the abbreviated and full names of each library, the number of the IBS book titles stored at each library, classification of the library (national, local or private), the name of prefecture where the library is located, and annotations.

Figure 2 is a printed example from the IBS master file in Excel format. Each line corresponds to a book title. The first column gives the phonetic reading expressed in the Japanese alphabet (*Kana*). This was necessary both because the formal titles in the second column, written by a mixture of *Kanji* (Chinese) and *Kana* characters, can

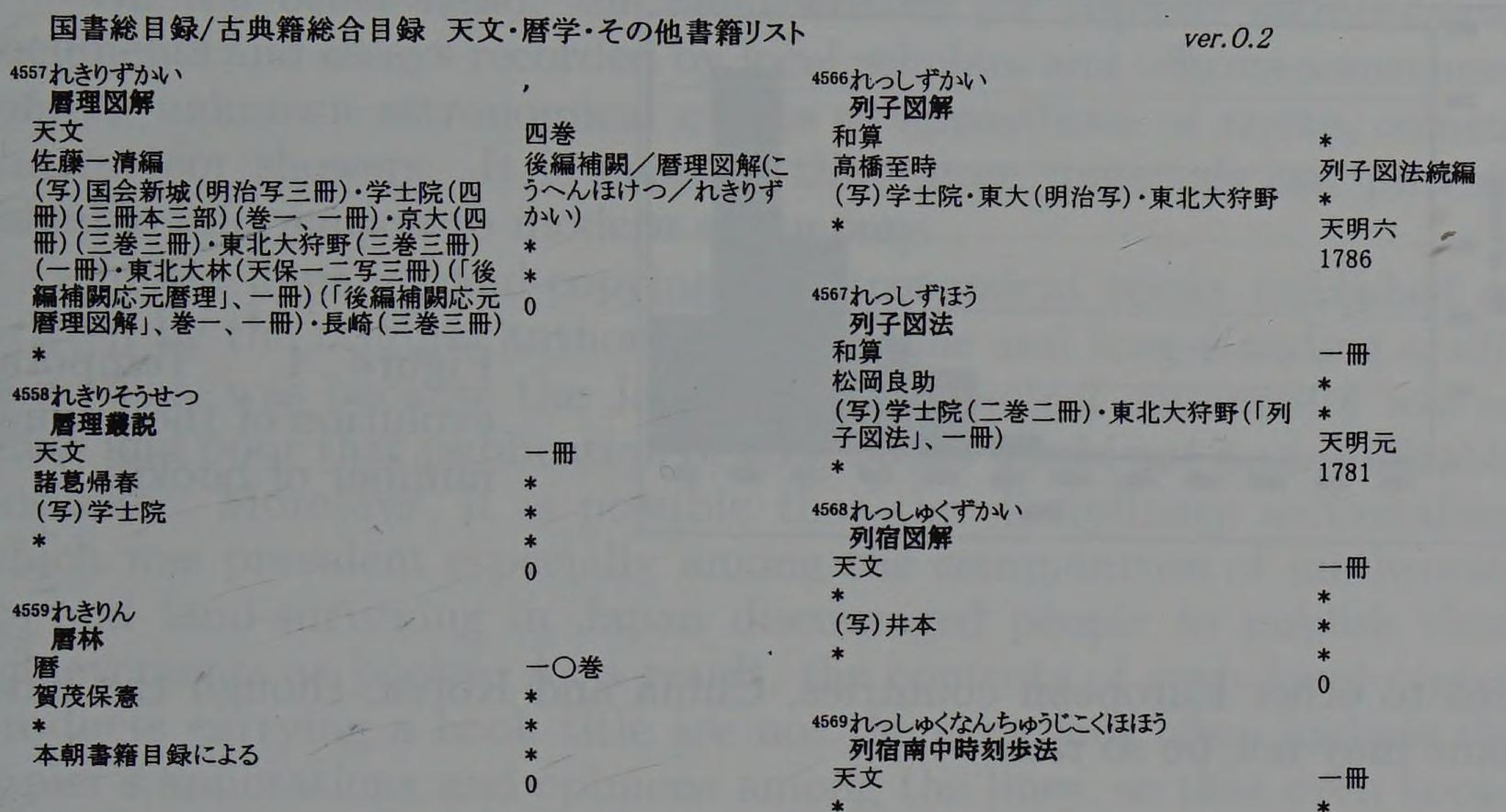
【読み】	【書名】	【巻冊】	【分類】	【著者】	【成立】		【所在】		【典拠】
あいづごよみ	会津暦	*	暦	*	享和二	***	(写)学士院(会	*	1802
あいづごよみのゆらい	会津暦之由来	一冊	暦	*	貞享三	***	(写)福島・会津	*	1686
あいづじんちょじゅつれき	会津人著述暦算書目録	一冊	和算	*	*	**	(写)学士院	*	0
あさだあきよししょかんな	麻田妥彰書翰并図面	一冊	天文	麻田剛立	天明三	**	(写)旧浅野	[illegible]	1783
あさだいのうりょうおうので	麻田伊能両翁之伝	一冊	伝記	*	*	**	(写)東北大岡本	*	0
あさだけ／りょうしょくじっ	麻田家／両食実測	一冊	天文	麻田剛立	寛政七頃	***	(写)尊経(西太	[illegible]	1795
あさだししょそくげっしょく	麻田氏所測月食	一冊	天文	麻田剛立	寛政頃	***	(写)石橋栄達	[illegible]	1789
あさだれき	麻田暦	二冊	暦	麻田妥彰(剛立)	天明六著者	***	(写)尊経	[illegible]	1786
あさのほくすいれきじゅつ	朝野北水暦術断片	一冊	暦法	*	*	***	(写)東北大狩野	*	0
あじませんせいべんもうの	安島先生便蒙之術	一冊	暦法・和	安島直円	*	***	(写)東北大狩野	[illegible]	0
あずまかがみてんちへん	東鑑天地変抄	一冊	暦法	*	*	***	(写)国会白井	*	0
あずまかがみれきさんかい	東鑑暦算改補	一冊	暦	安藤有益	延宝四	***	(写)東北大狩野	[illegible]	1676
あべかいちゅうでんれき	安部懐中伝暦	一冊	暦	*	寛永十九	***	(写)岩瀬	*	1642
あべのせいめいいじ	安倍晴明遺事	一冊	占卜	神林弼	*	**	(写)礫川	[illegible]	0
あべのせいめいてんもん	安倍晴明天文日取巻	一冊	暦	*	*	**	(写)平山清次	*	0
あべのせいめいものがた	安倍晴明物語	七巻六	仮名草子	浅井了意？	寛文頃刊	*	(版)延享二版	[illegible]	1661
あべのやすちかあそんき	安倍泰親朝臣記	*	暦	安倍泰親	仁安元	***		[illegible]	1166
あべはかせ／きびげんり	安部博士／吉備源流／晴明朝臣	*	天文	*	*	*	(写)青森	*	0
あまくさそくりょう	天草測量	*	地誌	伊能忠敬	*	***	(活)天草郡史料	[illegible]	0
あまのかいぞくしょ	天野海賊書	一冊	航海	*	*	***	(写)金沢市加賀	*	0

Figure 2. A sample output from *Inventory Book for Survey* (IBS) master file in Excel format.

sometimes be pronounced in different ways, and of course because of sorting convenience. The third column shows the number of volumes of the book, and the fourth is the description to which discipline the book belongs, such as astronomy, calendar, land-surveying, navigation, etc. The author name(s) is given in the fifth column. The sixth and the eighth represent the Japanese chronological year when the book was written or published, and the corresponding Christian Era, respectively. The seventh column refers to the library names that store each book title with a distinction of hand-written or published versions; all of the entries are not shown because of the limited space of this Table. All Excel cells without information are filled with an asterisk or zero-value.

Figure 3 is part of a page from the IBS printed-version of about 250 pages. This was printed using PageMaker, in which full information on each book title is displayed along with a serial number. For example, one can see that book No. 4557, *Rekiri Zukai* (illustrated explanation of calendar making), is stored in six libraries.

In 2003, we also sent a questionnaire investigation to about 250 libraries to find out whether those libraries had accepted new books from the Edo period after the completion of *Kokusho Somokuroku*. As a result, we learned that roughly 10% of the libraries recently bought or were donated new book titles, although only 40% of the above libraries responded to our questionnaire. We plan to continue sending similar questionnaires to other libraries.



国書総目録/古典籍総合目録 天文・暦学・その他書籍リスト ver.0.2

4557れきりずかい
暦理図解
天文
佐藤一清編
(写)国会新城(明治写三冊)・学士院(四冊)(三冊本三部)(巻一、一冊)・京大(四冊)(三巻三冊)・東北大狩野(三巻三冊)(一冊)・東北大林(天保一二写三冊)(「後編補闕応元暦理」、一冊)(「後編補闕応元暦理図解」、巻一、一冊)・長崎(三巻三冊)
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四巻
後編補闕/暦理図解(こうへんほけつ/れきりずかい)
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0

4558れきりそうせつ
暦理叢説
天文
諸葛帰春
(写)学士院
*

一冊
*
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4559れきりん
暦林
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一〇巻
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4566れっしずかい
列子図解
和算
高橋至時
(写)学士院・東大(明治写)・東北大狩野
*

*
列子図法続編
*
天明六
1786

4567れっしずほう
列子図法
和算
松岡良助
(写)学士院(二巻二冊)・東北大狩野(「列子図法」、一冊)
*

一冊
*
*
天明元
1781

4568れっしゅくずかい
列宿図解
天文
*
(写)井本
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*
0

4569れっしゅくなんちゅうじこくほほう
列宿南中時刻歩法
天文
*

一冊
*

Figure 3. Sample page of the IBS printed version.

4. Progress till 2003

4.1. Overseas outcome

As concerns Japanese materials stored at overseas libraries, we picked up candidate libraries for survey based on the Union Catalogue of Early Japanese Books in Europe prepared by Peter Kornicki (Cambridge Univ.) and Hayashi Nozomu, which is available at the National Institute of Japanese Literature[2]. Although the catalogue lists a considerable number of the libraries having Japanese books, the majority of them do not store old books of the Edo period, but only modern ones.

Some of the libraries that our team members visited and could list the historical books on astronomy till March 2003 are: East Asian Library of Columbia Univ., US Library of Congress, Univ. of California Los Angeles and Berkeley, Yenching Institute of Harvard Univ., British Library, London Univ., Cambridge Univ., Shanghai Municipal Library, Taiwan Univ., Taiwan Univ. of Education, Gugong Palace Library (Taiwan), and others. After 2003, we plan to extend our survey

[2] Although National Institute of Japanese Literature publishes the list of *Kokusho Somokuroku* via Internet (`http://www.nijl.ac.jp/`), the whereabouts of each book are not included.

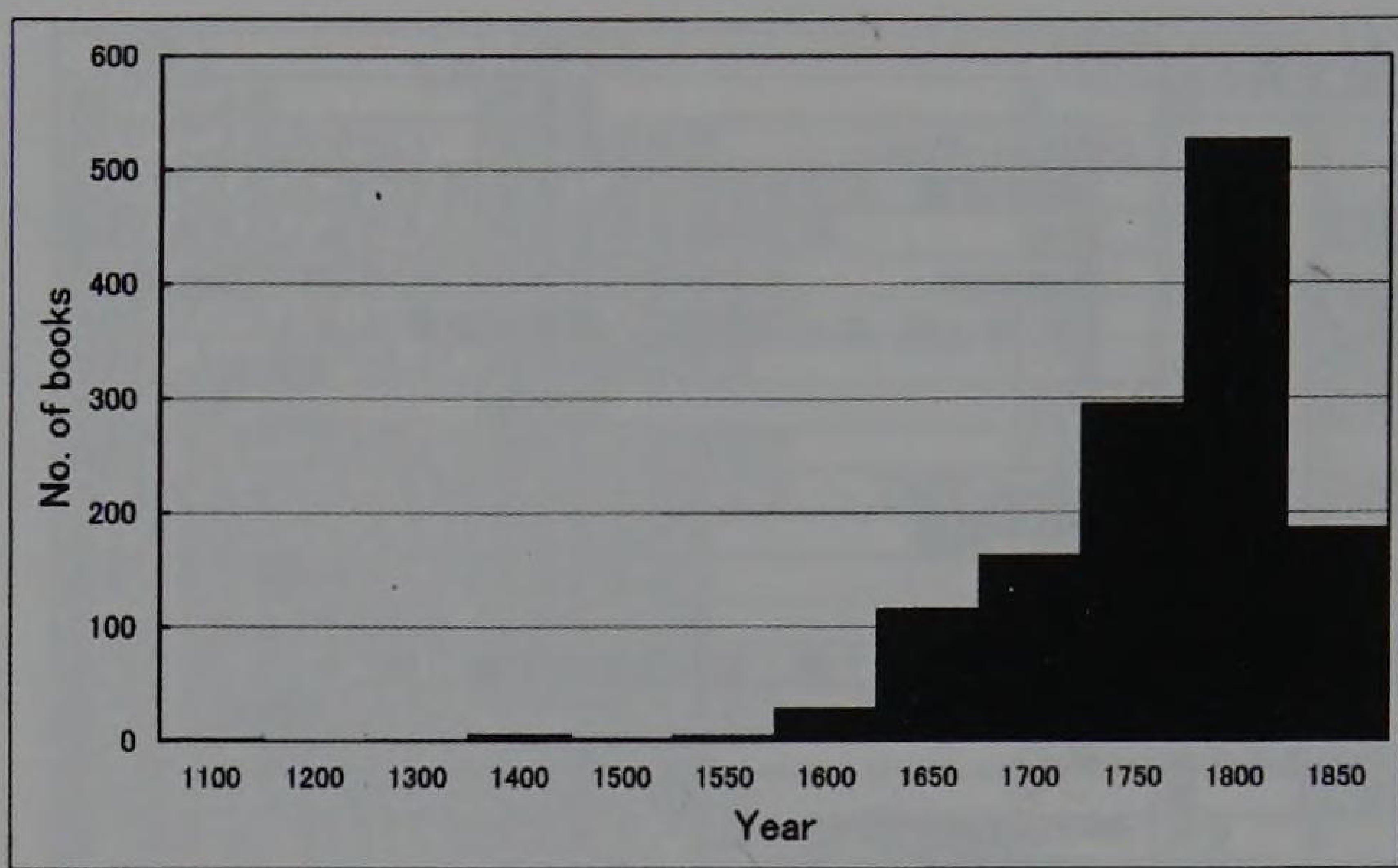

Figure 4. Temporal evolution of the annual number of books.

area to other European countries, China and Korea, though the outcome may not be so rich.

4.2. Domestic outcome

Regarding domestic libraries and museums, each team member was responsible for surveying at least 3–4 prefectures. As a result, astronomy-related books and materials before 1870 not included in IBS were gathered and catalogued for 73 major libraries from 30 prefectures. The total number of listed new books amounted to about 1300 till 2003, and among them, 15–20% are likely to be new titles. The full list of new books is given in our Interim Report (Nakamura 2003). Work to combine the list with thumb-nail photos of the cover page of each book is also underway in Excel format.

5. Characteristics of Existing Japanese Sources Related to Astronomy

Japanese astronomy had been under Chinese influence from antiquity till the 18^{th} century, and thereafter was affected by modern western astronomy of Portuguese and Netherlands origin. Because of that, a considerable fraction of Japanese astronomical literature in printed form was devoted to such topics as the technical discussion of the Chinese calendars as represented by the *Shoushi* calendar of the Yuan dynasty, elementary western astronomy taught through the Chinese popular book *Tianjing Huowen* (Yu Yi, ca. 1675), and the Buddhist astronomy/cosmology (Nakayama 1969). Our survey investigation confirmed the trend pointed out by Nakayama.

On the other hand, the hand-written (or copied) astronomical documents and essays recorded by local scholars and officers sometimes contain unknown astronomical events as apparitions of novae, comets and meteor showers. It is possible that those materials can provide valuable information to modern astronomy.

In old Japan, hand-copying of astronomical books published or written by the original authors was a unique and long-standing tradition. This was because the Japanese astronomical community was so small and poor that publication of such books would not be a profitable business. Moreover, it is possible that the disciplinary sectionalism which was prevalent especially among the communities of mathematics and land-surveying in Japan discouraged people to publish their achievements as books. As a result, the contents of such hand-copied products carrying a book title are not the same but often include the copier's annotations and opinions among the lines, so that even books with the same title often need careful comparison in making the inventory.

By analyzing about 4600 book entries in IBS, we found that only 16% (667 out of 4596) belong to printed books, while another 84% (3599 out of 4596) are hand-written (copied) books; the latter fraction seems to be unusually high in comparison with European countries, China and Korea. Such a hand-copy tradition causes another problem. It was a common custom that a person who wanted to read a book, copied it for his own sake by borrowing it from another person. In such cases, the copier often omitted copying the date when the original book was written or published. This is likely the main reason why many copied books lack a year. According to our analysis, only 29% (1329 out of 4599) of IBS books carry the year of publication or writing, whereas another 71% (3266 out of 4599) do not.

Figure 4 shows the number distribution of "with-year" books as a function of time (in half-century steps). One can see that just a few per cent of the "dated" books were written or published before the Edo period. It is possible that the percentage of books belonging to the pre-Edo period may double if we scrutinize "undated" *Yinyang* astronomical books, since it is known that *Yinyang* astronomical divination and horoscopic arts were popular in medieval Japan.

The steep rise of the book number during 1750–1800 probably corresponds to the most stable time in the Edo period, during which the monetary economic system was developed along with the increase of agricultural and industrial activities, and as a result the people could afford being interested in non-practical things like astronomy. On the

other hand, the number decrease towards the mid-nineteenth century reflects the social unrest of Japan caused by strong opposing movements against the long-standing seclusion policy; in such situations astronomy was obviously of little interest.

6. Summary

In 2002 we launched the Japanese Astronomical Archives Project for the Edo period (prior to 1870). We compiled an Inventory Book for Survey (IBS) of ~250 pages, with about 4600 book titles, in computer-readable formats. We discussed the specific nature of existing Japanese historical materials relating to astronomy, through statistical analysis. By 2003, we have collected approximately 1300 new books from both domestic and overseas survey investigations, and among them, 15–20% were likely to be new titles. After completion of the four-year research, we plan to publish a General Inventory of Japanese Historical Resources Relating to Astronomy. We expect that this will be of help in clarifying matters as:

1. spiritual and cultural continuity in astronomy between the Edo era and the modern post-Edo period,

2. the evolution of regional and temporal spreading of astronomical books of wider interest, and

3. the origin of translated astronomical terminology, etc.

Acknowledgements

My first gratitude is due to kind and generous cooperation given by both the overseas and domestic libraries and museums that we have surveyed so far, though to my regret I cannot list the individual names here because of the limited space. I also express my hearty thanks to the co-investigators and collaborators of our team. This work was supported by Grant-in-Aid for Scientific Research on Priority Areas, No.14023112, of the Ministry of Education, Culture, Sports, Science and Technology, Japan.

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ASTRONOMICAL HERITAGES: Astronomical Archives and Historic Transits of Venus
Journal of Astronomical Data, Vol. 10, 7, 2004
Christiaan Sterken, Hilmar W. Duerbeck, eds.

An Introduction to the Astronomical Archives of Australia and New Zealand

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Abstract

After summarising key elements in the astronomical histories of Australia and New Zealand, we provide master lists of the principal astronomical records found in the archives, libraries, museums, observatories and government research institutes of these two Oceanic nations. In preparing these two national inventories, we address one of the primary objectives of the IAU's Working Group on Astronomical Archives.

1. Introduction

International Astronomical Union Commission 41 (History of Astronomy) was formed in 1948, but it was only in 1991 that the Commission's first Working Group – on Astronomical Archives – was formed. This was largely in response to the on-going dispersal and destruction of personal papers of astronomical importance, a matter of considerable concern that was raised at the 1967, 1979 and 1988 General Assemblies.

Chaired by the upcoming President of C41, Suzanne Débarbat, the Astronomical Archives Working Group was a joint initiative of Commissions 5 (Documentation and Astronomical Data) and 41, and its initial objectives were reflected in Resolution C4 which was passed at the 1991 General Assembly "to establish a register of the whereabouts of all extant astronomical archives of historical interest; to impress on observatories and other institutions their responsibility for the preservation, conservation, and where possible, cataloguing of such archives; and to search for an institution that will allocate space and funds for maintaining such a register and publishing it" (see Débarbat 2002).

Perhaps most challenging in that it would involve a long-term co-ordinated international effort was the first of these objectives, and the Working Group's strategy was to begin by encouraging colleagues "...to build up national inventories of astronomical archives in different countries, and to document, research and disseminate information on individual archives, and on individual archival records" (Débarbat 2002). This paper represents a contribution towards this key objective by presenting two national inventories: for Australia, and neighbouring New Zealand. Critical here was an acceptable definition of the term "astronomical archives of historical interest" mentioned in objective number 1, above, for this would determine which specific records would or would not feature in the inventories. After some deliberation, I decided to only include archives that related to individuals and/or observatories that (a) made a significant contribution to world astronomy, or (b) made a long-term local or national contribution to astronomy.

In the first of these criteria, the term "significant contribution" was loosely interpreted to accommodate any astronomer who published *on a regular basis* in leading astronomical journals, not just those who were at the forefront of astronomical research and are now deemed by international consensus to have been the leading practitioners of the day. By contrast, when it came to the second criterion the decision was made to include not just observational astronomers, but also those who were particularly active instrument-makers, who contributed in a positive and sustained way to the popularisation of astronomy, or who played a leading role in the development and success of local or national astronomical societies.

This research paper documents historically-significant astronomical archives held in Australian and New Zealand repositories, but it is important to remember that if definitive histories of astronomy are to be prepared for these two countries then resources in other, non-local, repositories must also be consulted. Such records can be found in various overseas countries, but especially in England at the RGO Archives in Cambridge and at the RAS Archives in London (see Bennett 1978). For an extensive listing of Australian and New Zealand astronomical archives in British repositories the reader is referred to Mander-Jones's (1972) masterful *Manuscripts in the British Isles Relating to Australia, New Zealand, and the Pacific.* Meanwhile, the Mitchell Library in Sydney contains important manuscript material relating to New Zealand astronomical history, and this is discussed in Orchiston (1985).

2. Australian Astronomical Archives

2.1. Australian astronomy: a potted history

Although Australia has an Aboriginal astronomical history that dates back more than 40,000 years (Haynes 2000), scientific astronomy only arrived with European explorers during the late eighteenth century, and the first permanent astronomical facility, the short-lived Dawes Observatory in Sydney, was established in 1788. Parramatta Observatory existed from 1821 to 1847, and during the second half of the nineteenth century Government-funded observatories were established in Melbourne, Sydney, Adelaide and Perth (Haynes et al. 1996; Orchiston 1988). The critical period, 1850–1899 also witnessed the founding of the nation's first astronomical groups and societies (Orchiston 1998a); the emergence of the first home-grown amateur telescope-makers (Orchiston 2003); visits to Australian shores by overseas astronomers belt on observing the 1874 and 1882 transits of Venus (e.g. Orchiston & Buchanan 1993); and the appearance of Australian amateur astronomers of international importance (Orchiston 1989). Most prominent of these was John Tebbutt, who for the last three decades of the century was arguably Australia's foremost astronomer (Orchiston 2004; White 1979).

A feature of Australian astronomy between 1880 and 1920 was the continued adherence to positional astronomy by the nation's professional observatories, at the expense of the newly-emerging astrophysics, and it was only with the founding of the Commonwealth Solar Observatory near Canberra in 1924 that forefront astronomy once more took root in Australia (Allen 1978; Haynes et al. 1996). The 1940s would see this institution shift its focus to non-solar astronomy and change its name to Mount Stromlo Observatory (Frame & Faulkner 2003).

Another important development that occurred in Australian astronomy during the 1940s was the emergence of the CSIRO's Division of Radiophysics, which quickly became an international leader in the new field of radio astronomy (see Sullivan 1984). Over the years, such instruments as the Potts Hill grating interferometers, Dapto radio spectrographs, Parkes Radio Telescope, Culgoora Radioheliograph and Australia Telescope all assumed international importance (see Haynes et al. 1996; Robertson 1992).

The final phase in the evolution of Australian astronomy was the development of undergraduate courses, post-graduate degrees and research facilities by many of the nation's universities. Most prominent were the University of New South Wales and Sydney University in

the state of New South Wales; the Australian National University, in the Australian Capital Territory; Monash and Melbourne Universities in Victoria; the University of Tasmania; and Adelaide University in South Australia. In addition to strengths in optical and radio astronomy (including astro-chemistry), a number of Australian institutions pursued theoretical studies, infrared, gamma-ray, X-ray and cosmic ray astronomy, and radar observations of meteors. For a useful overview of university astronomy in Australia see Haynes et al. (1996).

2.2. Master list of significant astronomical archives

Table 1 contains a listing of the most significant astronomical records held in various Australian repositories. Useful listings and summaries of some of these records have already been published[1], but more extensive descriptions of many of these are warranted. As a start in this direction, note that the Duffield and Giovanelli Papers are discussed in detail by McCarthy & Sankey (1987) and McCann & McCarthy (1989) respectively, while Orchiston et al. (2004) provide a well-illustrated overview of the ATNF's unique Historic Photographic Archive (which provides a rich pictorial perspective on the history of Australian radio astronomy). Meanwhile, these Proceedings includes a report on the Tebbutt Papers in the Mitchell Library.

3. New Zealand Astronomical Archives

3.1. New Zealand astronomy: a potted history

New Zealand was one of the world's last major land masses to be settled by man, between 750 and 1000 years ago, and the Maori occupants had an intricate astronomical knowledge system (Best 1922; Orchiston 2000) that was only superseded with the arrival of the first European settlers, and particularly the astronomers on Cook's three voyages to the South Seas (see Orchiston 1998b).

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[1]References in Table 1 refer to [1]Cross 1973; [2]Mourot 1973; [3]McCarthy n.d.: 53; [4]Mozley n.d.: 19, 98; [5]Mozley n.d.: 99; [6]Orchiston 2004; [7]Mozley n.d.: 41, 98; [8]Drake 1973; [9]Mozley n.d.: 91; [10]McCarthy n.d.: 173; [11]Chambers 1995, [12]Orchiston et al. 2004; [13]Mozley n.d.: 83; [14]McCarthy & Sankey 1987; [15]Mozley n.d.: 89; [16]McCann & McCarthy 1989; [17]Haenke 1973; [18]McCarthy n.d.: 3; [19]Mozley n.d.:78–79; [20]McCarthy n.d.: 60; [21]McCarthy n.d.: 20; [22]McCarthy n.d.: 194; [23]Mozley n.d.: 1, 115; [24]Mozley n.d.: 90.

Table 1. Master list of Australian astronomical archives. Type refers to State (S), Jesuit (J) and National (N) archives.

Repository and Records Held	Type	Reference
Archives Office of New South Wales, Sydney	S	1
Parramatta Observatory records		
Sydney Observatory records		
Mitchell Library, Public Library of N.S.W., Sydney	S	2
Dawes Papers		3
Parramatta Observatory records		4
Macdonnell Papers		
P.P. King Papers		
Russell Papers		5
Tebbutt Papers		6
Dixon Library, Public Library of N.S.W., Sydney	S	
Parramatta Observatory records		7
Powerhouse Museum, Sydney	S	
Sydney Observatory records		
Riverview College Archives, Sydney	J	
Riverview Observatory records		8, 9
National Archives of Australia, N.S.W. Branch, Sydney	N	
Parramatta Observatory records		10
CSIRO Division of Radiophysics records		11
CSIRO Division of Physics records		
CSIRO Australia Telescope National Facility, Sydney	N	
CSIRO Division of Radiophysics records		12
CSIRO Australia Telescope National Facility records		12
Basser Library, Australian Academy of Science, Canberra	N	
Mount Stromlo records		13
Duffied Papers		14
Pawsey Papers		15
Giovanelli Papers		16
National Archives of Australia, Canberra	N	
Melbourne Observatory records		17
National Library of Australia, Canberra	N	
Parramatta Observatory letters		15
C.W. Allen Papers		18
State Library of Victoria, Melbourne	S	
Melbourne Observatory records		19
Public Record Office of Victoria (Melbourne)	S	
Melbourne Observatory records		20
Tasmanian Library (Hobart)	S	
Records of notable amateur astronomers		
Archives Office of Tasmania, Hobart	S	
Records of notable amateur astronomers		21
Mortlock Library, Adelaide	S	
Adelaide Observatory records		22
State Records of South Australia, Adelaide	S	
Todd Papers		23
Perth Observatory, Perth	S	
Perth Observatory records		24

In Wellington, the nation's capital, a Provincial Observatory was established in 1864, and just five years later this was relocated to a nearby site and reconstituted as the Colonial Observatory – now with national rather than local responsibilities (Eiby 1977). New Zealand's attractive location proved a drawcard for British, French, German and U.S. transit of Venus expeditions in 1874 and/or 1882 (e.g. see Orchiston et al. 2000), and during the last two decades of the nineteenth century Canterbury University College's charismatic Professor Bickerton captivated audiences at home and abroad with his 'partial impact theory' (Gilmore 1982).

One feature of New Zealand's shortage of professional astronomy positions and its small scattered communities was the emergence of a national network of amateur astronomers, some of whom soon established international reputations (and in some cases *de facto* 'city observatories'). Most prominent were John Grigg of Thames (Orchiston 2001b), Joseph Ward of Wanganui (Orchiston 2001a, 2002) and later Auckland's Ronald McIntosh (Bateson 1977), while Charlie Gifford's hallmark papers on the meteoritic origin of the lunar craters escaped wide recognition at the time because they were published in a generalist New Zealand scientific journal (see Hoyt 1987).

In 1907 the Colonial Observatory was replaced by the Hector Observatory, the primary role of which was to provide a national time-service. In 1925 it was renamed the Dominion Observatory, and its research focus shifted to seismology, so it was only in 1941, with the founding of the Carter Observatory (also in Wellington), that astronomical research would once again attain any momentum in New Zealand (Orchiston & Dodd 1995). Partly as a result of this professional vacuum, the various observing Sections of the Royal Astronomical Society of New Zealand assumed national prominence – and in the case of the Variable Star Section, international eminence, under the capable leadership of Dr Frank Bateson (see Bateson 1989).

Although New Zealand hosted a number of radio astronomy research projects in 1945 and the immediate post-war years (Orchiston 1994), it was the radar meteor astronomy of Ellyett and Keay at the University of Canterbury in the 1950s that quickly received international recognition (see Keay 1965). But the final phase in the professional development of astronomy in New Zealand only occurred when the University of Canterbury founded the Mount John University Observatory and developed vibrant undergraduate and post-graduate programs (Cottrell 1991a; Tobin & Evans 1996). Academic astronomy later blossomed, but on a much smaller scale, at the University of Auck-

Table 2. A master list of New Zealand astronomical archives.

Repository and Records Held
Auckland Observatory (Auckland)
Auckland Astronomical Society records
Auckland Observatory records
Ward Observatory (Wanganui)
Ward papers
Ward Observatory records
National Archives (Wellington)
Colonial Observatory records
McIntosh Papers
Alexander Turnbull Library (Wellington)
Bateson Papers
Bickerton records
Cawthron Solar Observatory site-testing records
Gifford records
Stock records
U.S. 1874 Chatham Islands transit of Venus expedition records
Carter Observatory (National Observatory of New Zealand, Wellington)
Adams Papers
Bickerton Papers
Carter Observatory records
Colonial Observatory records
Gifford Papers
Grigg records
Maori astronomy records
Royal Astronomical Society of New Zealand records
Wellington City Observatory records
Museum of New Zealand Te Papa Tongarewa (Wellington)
1874 and 1882 transits of Venus records
Colonial Observatory records
Solander telescope records
Marist Fathers of New Zealand Archives (Wellington)
Meeanee Observatory records
Hocken Library, University of Otago (Dunedin)
Beverly records
Skey records

land, Victoria University of Wellington and at the University of Otago in Dunedin (Cottrell 1991b).

3.2. Master list of significant astronomical archives

Table 2 contains a listing of the most significant astronomical records held in various New Zealand repositories. In contrast to the Australian

astronomical archives, it is notable that no descriptions or listings have been published of any of these New Zealand records. This is an urgent challenge for New Zealand historians of astronomy.

4. Concluding Remarks

Significant astronomical records are to be found in seventeen different Australian repositories, comprising seven archives, seven libraries, a museum, an observatory and a national radio astronomy institute. These are scattered throughout Australia, in almost every state, and even though Canberra is the national capital, this city is home to just three repositories (18% of the total), as opposed to Sydney's seven repositories (41% of the total). Most Australian institutions with astronomical records employ staff trained in the care and maintenance of archival material, provide storage facilities that meet international standards, and have access to professional conservators if required. On this basis, the future of Australia's astronomical archives looks secure. If there is a 'downside' though, it relates to the absence of any published catalogues or lists of the Sydney Observatory records in the Archives Office of New South Wales and the Powerhouse Museum, and the Melbourne Observatory records in the State Library of Victoria and Public Record Office of Victoria. These are urgently needed.

Important New Zealand astronomical records are housed in eight different repositories: three observatories, two archives, two libraries and a museum. Five of these institutions (62.5%) are located in Wellington, the nation's capital. Unlike the Australian astronomical records, there are no published catalogues or lists of any of the New Zealand astronomical archives mentioned in Table 2, and this remains an immediate priority. Furthermore, none of the observatories included in this Table currently employs a trained archivist, and the conditions under which the astronomical records are stored in these three institutions leaves much to be desired. It will take considerable time, money and effort to bring the astronomical archives of New Zealand – as a whole – up to the standard enjoyed by their Australian counterparts.

Acknowledgements

I wish to thank the staff at many of the institutions mentioned in Tables 1 and 2 for their assistance and support during my research

visits, and for supplying information relevant to this survey. I am also grateful to the IAU for awarding me a Travel Grant which allowed me to attend the General Assembly, where an earlier version of this study was presented as part of a larger paper that also dealt with the extant historically-significant telescopes of Australia and New Zealand.

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Journal of Astronomical Data, Vol. 10, 7, 2004
Christiaan Sterken, Hilmar W. Duerbeck, eds.

Highlighting the History of Nineteenth Century Australian Astronomy: The Tebbutt Collection in the Mitchell Library, Sydney

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ABSTRACT

After providing a biographical sketch of John Tebbutt, Australia's foremost nineteenth century astronomer, this paper summarises the collection of Tebbutt archives in the Mitchell Library, Sydney, and discusses some individual record lost in detail. The 'Tebbutt Collection' is an indispensable resource for those studying nineteenth and early twentieth century Australian astronomy, but it also throws light on the state of British, South African and New Zealand astronomy at this time.

1. Introduction: the C41/ICHA Archives Working Group

The Archives Working Group of the IAU was formed in 1991 with a view to (1) establishing a register of the whereabouts of surviving historically-significant astronomical archives, and (2) encouraging observatories and other institutions to preserve, catalogue and conserve such archives (Débarbat 2002).

In response to the first of these goals, at the Manchester IAU General Assembly in year 2000 I presented a paper on the historically-significant astronomical archives in Australian and New Zealand repositories (see Orchiston 2004a), with a view to providing basic national inventories for these two Oceanic nations.

Given these two national lists, the task now confronting astronomical historians is to describe and document the contents of individual collections or repositories in these two countries. This paper is such a

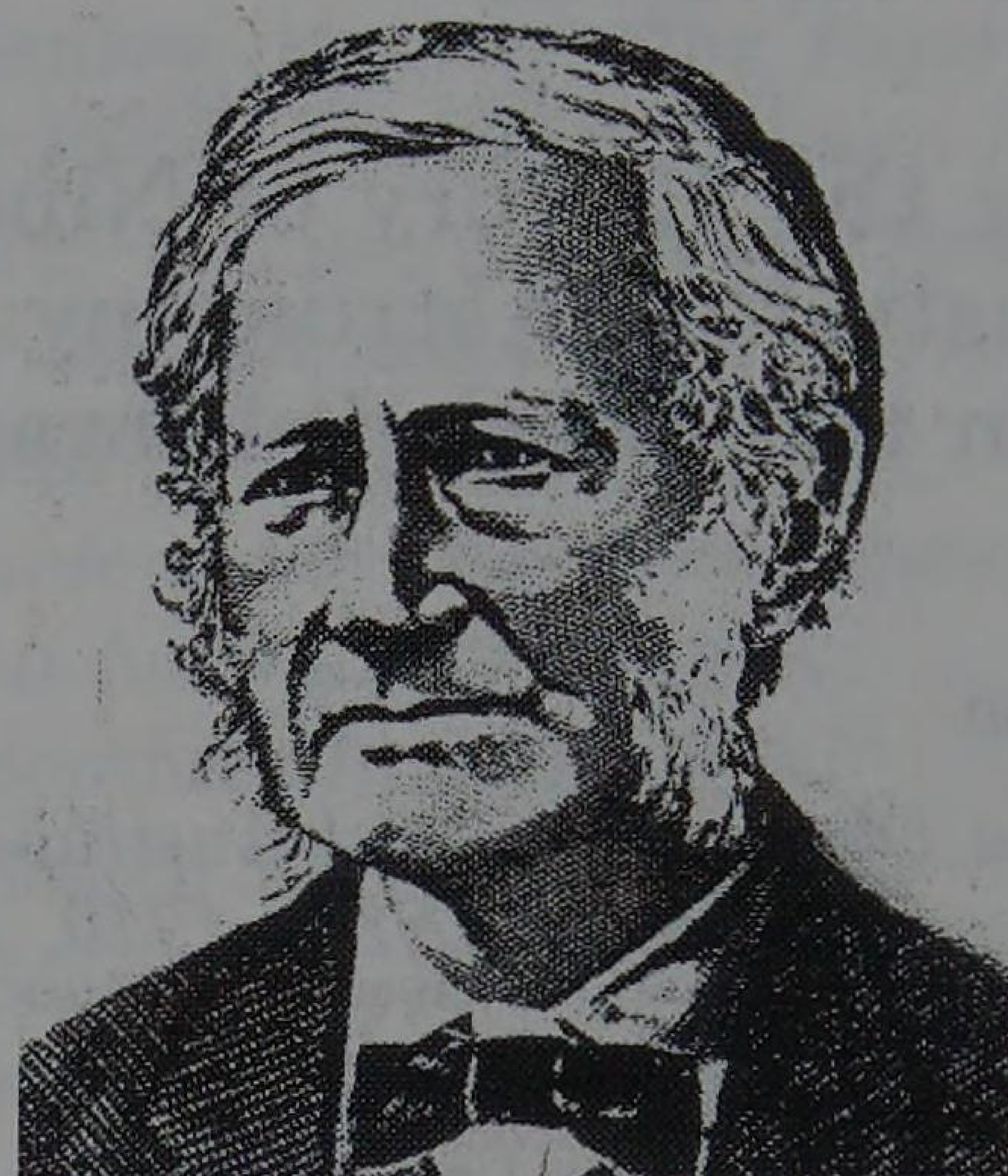

Figure 1. John Tebbutt, 1834–1916 (Orchiston Collection).

contribution, and focuses on the 'Tebbutt Collection' in the Mitchell Library, Sydney (mentioned, in passing, in Mourot 1973). But before doing this, I will briefly discuss John Tebbutt's achievements in order to show why the Tebbutt Collection is of importance and deserves our attention.

2. John Tebbutt: an Overview

John Tebbutt (Fig. 1) is Australia's most outstanding amateur astronomer, and during the nineteenth century enjoyed an international reputation among those committed to positional astronomy (see Orchiston 1988d, 1989; White 1979). He was born in Windsor, New South Wales (~50 km northwest of central Sydney), on 25 May 1834, and spent his adult years as a successful farmer and businessman, dying in Windsor on 29 November 1916. He was predeceased by his wife, but survived by four of his seven children.

Early in life Tebbutt developed a deep interest in astronomy, and at the age of nineteen he began systematic observing, which led ultimately to the discovery of C/1861 J1, the Great Comet of 1861 (Orchiston 1998a). Shortly after, he was offered but declined the Directorship of the Sydney Observatory (Orchiston 1988c). Determined to make his mark as an independent astronomer, he purchased an 8.3-cm Jones refractor and in 1864 installed this and a transit telescope in what was to be the first of four different Windsor Observatory buildings (Orchiston

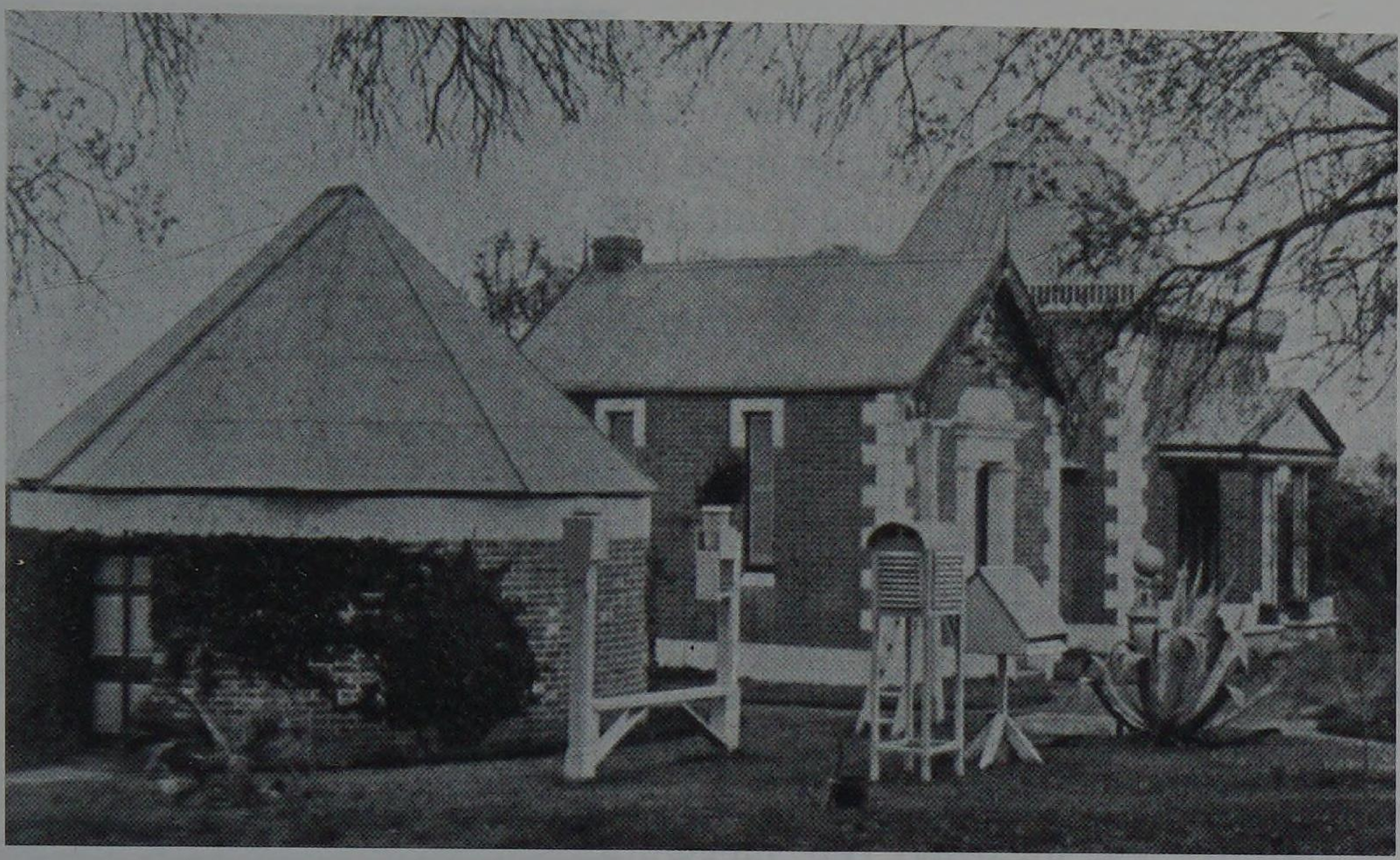

Figure 2. Two of the Windsor Observatory buildings in 1906. On the left is the 'equatorial house' built in 1894 for the Grubb telescope, and beyond it the 1879 main observatory building, which housed the Cooke refractor and Tebbutt's extensive research library (Orchiston Collection).

1988b). Figure 2 shows two of these. Larger refractors, of 11.4-cm and 20.3-cm aperture, followed in 1872 and 1886 respectively (see Orchiston 2001a; Tebbutt 1887), and a truly staggering succession of scientific observations – mainly of comets, planets, minor planets, Jovian satellite phenomena, lunar occultations (of stars *and* planets), solar and lunar eclipses, transits of Mercury and Venus, variable stars and double stars (Orchiston 2000, 2004b). In addition, he continued intermittent comet-seeking, and in 1881 made a second discovery, C/1881 K1 (Fig. 3), which likewise turned out to be a Great Comet (Orchiston 1999a). He also discovered Nova V728 Scorpii 1862 (Ashbrook 1984; White 1979). Fundamental to this research programme was an impressive reference library "...such as few private establishments can boast of." (Tebbutt 1908: 112). This relied on publication exchanges with individuals and observatories in thirty-three different countries (see Orchiston 2004b).

Apart from his ambitious observational programs, Tebbutt also popularised astronomy through personal correspondence, by lecturing, conducting occasional public nights at the Windsor Observatory for invited guests, and publishing prolifically in the local and Sydney news-

papers (see Orchiston 1997). Apart from astronomy, he offered a local time service, maintained a fully-equipped meteorological station, and operated a tide gauge on nearby flood-prone South Creek. Over a fifty-year period he published more than 388 research notes and papers on his scientific work in local and overseas journals (but particularly *Astronomische Nachrichten* and *Monthly Notices of the Royal Astronomical Society*), as well as two books, eight meteorological monographs, a number of booklets, and between 1888 and 1903, attractive little Annual Reports of the Windsor Observatory.

In 1873 Tebbutt was elected a Fellow of the Royal Astronomical Society, and in 1881 he founded Australia's first national astronomical group, the short-lived Australian Corps of Comet Observers (Orchiston 1982). In 1895 he served as President of the New South Wales Branch of the British Astronomical Association when this body was formed in Sydney (Orchiston 1988a).

Tebbutt was awarded the Jackson-Gwilt Medal and Gift by the Royal Astronomical Society in 1905 for his long and valuable service to astronomy – he was only its third recipient. In more recent years, his face and Windsor Observatory have featured on an Australian $100 banknote, and a crater on the Moon has been named after him. John Tebbutt lived a long life, and made a significant contribution to world astronomy. Despite his amateur status, he was a major power-broker in nineteenth century Australian astronomy (e.g. see Orchiston 2002).

3. The Tebbutt Collection

3.1. Background and listing

When Tebbutt died in 1916, none of his surviving children was interested in astronomy, so dispersal of his astronomical records, his library, and his telescopes was inevitable. In July 1917, just seven months after Tebbutt's death, his son, John T. Tebbutt, arranged for most of the Windsor Observatory astronomical library, volumes of inward letters, and original observing books, journals, notebooks, diaries and other astronomical and meteorological records to be donated to the Mitchell Library in Sydney, in memory of his father. The Mitchell Library is a repository of books and manuscripts relating to the history of the Australia-Pacific region. A major research facility by international standards, the Mitchell Library is part of the State Library of New South Wales in Sydney, and was founded when David Scott Mitchell

Figure 3. Comet C/1881 K1 (Tebbutt) was a spectacular naked eye object that contributed significantly to cometary photography and spectroscopy (Courtesy: Chapin Library, Williams College).

"... bequeathed his unrivalled collection, with an endowment, to the Trustees of the Public Library of New South Wales. A condition of this bequest is that the collection and additions to it must be permanently kept as a separate library. Since its foundation the Mitchell Library has been further enriched by many important gifts as well as purchases." (The Mitchell Library..., 1967).

The Tebbutt Collection was one such important gift, and its donation was entirely in accordance with John Tebbutt's wishes. Indeed, it was his close British Astronomical Association New South Wales Branch colleague, Hugh Wright, who first raised this delicate matter in writing with him back in 1908: "There is a matter I wish you would consider – that is the preservation, *for posterity*, of your MS., journals, letter books, letters received, &c. Will descendants value this material? You cannot be sure. It would be a pity for your records to be dispersed ..." (Wright 1908; his underlining). Wright went on to mention a new fire-proof building at the Library, where the material could be kept together as the 'Tebbutt Collection'. Wright raised the matter again in 1912, by which time he was Mitchell Librarian and Tebbutt was in his twilight years at 78 years of age. In this same year he accepted on behalf of the Library bound copies of Tebbutt's papers published by the Royal Astronomical Society and the Royal Society of New South Wales, and was moved to write: "In collected form the papers will be readily available to any student who desires either to work

Table 1. Summary of the Tebbutt Collection: item, volumes, catalogue numbers.

Item	Vol.*	Catalogue Nr.
Inward letters, 1860–1915	47	A3682-A3728
Astronomical journals, 1853–1902	17	A3745^{-1}, A3747–A3758, A3783–A3786
Observational note books, 1862–1865, 1879–1882, 1884–1905	15	A3760–A3774
Calculations; Reduction of observations, 1853–1910	19	A3729–A3744, A3745^{-2}, A3746, A3775, A3780
Instrumental determinations, 1882–1901		A3759
Values of the wire of the transit instrument, 1885–1903		A3776
Determination of latitude, 1882		A3778
Determination of longitude, 1885–1887		A3777
Catalogue of the Observatory Library		A3781
Extracts from periodicals etc.		A3782
Observations during hot winds, 1862–1863	1	A3779
Meteorological observations, 1863–1913	13	A3787–A3799

*Not all items are in notebooks or bound volumes and can be easily quantified. Sometimes items are simply loose, or in folders, in tied labelled bundles.

up your scientific life-work or to study the achievements in Astronomy in Australia." (Wright 1912).

These sentiments reflect equally on the Mitchell Library's entire Tebbutt Collection, which is an incomparable resource for historians of nineteenth century Australian astronomy. It comprises 118 different record lots, which include inward letters; journals, diaries and observing notebooks; reductions of observations, and manuscripts of some completed papers; instrumentation records; latitude and longitude determinations; catalogues of the Windsor Observatory library; and meteorological observations (see Table 1).

Some of the items in this Table are self-explanatory and of little moment to most historians of astronomy, and therefore do not warrant further comment here. In contrast, other items contain invaluable research data. These are discussed below.

3.2. Inward letters

These forty-seven weighty, large-format bound volumes of letters, telegrams, postcards and other documents received by Tebbutt between 1860 and 1915 contain a wealth of information about Tebbutt and the

Table 2. List of Tebbutt's key correspondents.

Names	Affiliation
Cooke, Dodwell, Todd	Adelaide Observatory
Kingsmill, Shortt	Hobart Observatory
Baracchi, Ellery, Merfield, White	Melbourne Observatory
Brooks	NSW Lands Department
Cooke	Perth Observatory
Cooke, Egeson, Lenehan, Masters, Merfield, Pollock, Russell, Scott, Sellors, Smalley	Sydney Observatory
Beattie, Biggs, Bone, Brindley, Brownrigg, Butterfield, Close, Cobham, Colyer, Craven, Davidson, Fitchett, Furber, Gale, Heath, Hirst, Hoskins, Innes, Knibbs, Macdonnell, Martin, Megginson, Merfield, Morris, Nangle, Roseby, Ross, Swindlehurst, Tornaghi, Thomson, Wooster, Hugh Wright	Australian amateur astronomers
Chambers, Clerke, Crommelin, Denning, Gore, Johnson, Lynn, Maunder, Orr, Mary Proctor, Piazzi Smyth, Turner, Tupman, Wesley	U.K.
Auwers, Clemens, Kreutz, Rümker, Wolf	Germany
Veenstra	The Netherlands
Gill, Innes, Roberts and Voute	South Africa
Bickerton, Grigg, Stock, Ward	New Zealand
Mary Evershed	India
Doberth	Hong Kong
Burnham, W.W. Campbell, Coddrington, Harkness, Holden, Newcomb, Perrine, Peters, E.C. Pickering, W.H. Pickering, See, Todd	USA
Hussey, Perrine	Argentina, USA

Windsor Observatory, and about Australian and overseas astronomers and observatories – both amateur and professional.

Tebbutt maintained a voluminous correspondence with a great many astronomers, and Australian and foreign names of interest are given in Table ??.

In addition to Australian astronomy, and Tebbutt's own achievements, the inward letters cast useful light on aspects of overseas amateur and professional astronomy during the second half of the nineteenth century and early in the twentieth century, at a time when astronomy world-wide was witnessing the emergence of astrophysics, and the ultimate eclipse of positional astronomy.

Figure 4. *Left:* John Grigg, 1838–1920 (Courtesy Paul Angus). *Right:* One of Grigg's photographs of Comet C/1901 G1 (Courtesy: Mitchell Library, Sydney).

Obviously there is not space here to discuss the inward letters in detail, so we will focus on New Zealand astronomy and just the Grigg and Stock letters to illustrate the research potential of the Tebbutt Collection.

By the end of the nineteenth century, John Grigg (Fig. 4) was New Zealand's foremost amateur astronomer (see Orchiston 1998b), and he maintained a small private observatory with an 8.9-cm equatorial Wray refractor and a small transit telescope in the wealthy North Island gold-mining city of Thames. Although there are only twenty-four letters, dating between 1902 and 1907, from Grigg to Tebbutt in the Tebbutt Collection, and a number of letters from other astronomers that document aspects of Grigg's astronomy, these collectively tell us a great deal about Grigg's instrumentation and observatories (see Orchiston 2001b) and his various cometary discoveries (see Orchiston 1993) – including the evolving friction, at this time, between Australian and New Zealand amateur astronomers and Melbourne Observatory's Pietro Baracchi (Orchiston 1999b). Grigg was also a New Zealand astrophotography pioneer (Orchiston 1995), and one of the letters even includes photographs of Comet C/1901 G1 (for an example of one, see Fig. 4).

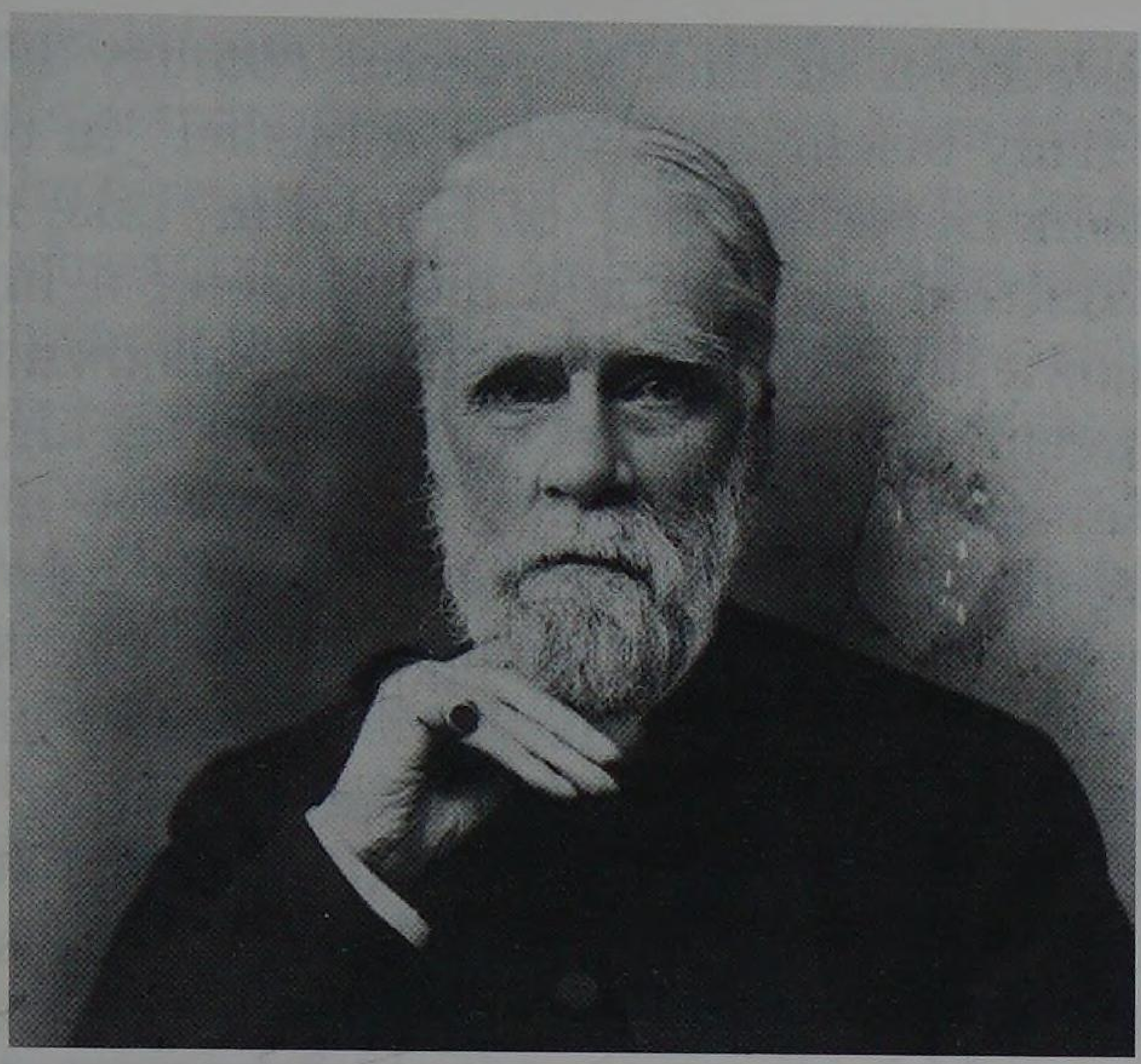

Figure 5. Arthur Stock, 1823–1901 (Courtesy of the Institute of Geological and Nuclear Sciences, Wellington).

The talented Reverend (later Archdeacon) Arthur Stock (Fig. 5) was the first Astronomical Observer at the government's Colonial Observatory when this was set up in the nation's capital, Wellington, but he also maintained a private observatory with a 8-cm and later a 10.4-cm refractor at his home (see Orchiston 1998b: 99–101). Twenty letters to Tebbutt dating between 1869 and 1886 document his independent discovery of Comet C/1881 K1 just one day after Tebbutt, and discuss his various observations of other comets and of the Moon, planets, lunar occultations, transits of Mercury and Venus, Jovian satellite phenomena, double stars and that enigmatic southern variable star, η Carinae. They also record something of his efforts to actively popularise astronomy, through the publication of two booklets, one on the up-coming 1874 transit of Venus (see Orchiston 1986). In addition, one of his 1869 letters outlines the principles of the coronagraph, fully sixty years before Lyot perfected the design and eleven years before Huggins came up with a similar idea.

One other New Zealand-related letter is of special interest, and deserves a mention here. Lieutenant-Colonel G.L. Tupman was in New Zealand to co-ordinate the British 1882 transit of Venus program, and during a visit to the South Island city of Dunedin he met and was so impressed with a local amateur astronomer named Arthur Beverley that he was moved to write the following (*inter alia*):

> "Since I have been in this wonderful country I have discovered "a truly bright light under a bushel" in the person of Mr. Arthur Beverley [sic.] of Dunedin. Like many distinguished Astronomers he is a mechanic of a high order, making his own microscope objectives on his own formulae; inventing ingenious apparatus and possessing high mathematical attainment's. In Europe he would be in the first rank among physicists & Astronomers. In New Zealand scarcely anyone knows his name – not one soul knows his merits. A watchmaker, I think, by trade, from an obscure part of Scotland, with consumption and another about as deadly disease, he made achromatic doublets of surpassing excellence for Sir David Brewster, Prof Thwaites & other distinguished men until he was able to pay his passage to New Zealand. There he soon saved as much as he required, or acquired enough somehow, chiefly by plying his trade, and at once gave up business to live & revel in botany, physics & astronomy. He quickly gets out the orbit of any comet that he sees and probably was the first to find that of the present comet...
>
> It is right that you should know what a neighbour you have. He only possesses a three inch achromatic, but it is very good and very well mounted equatorially, with circles graduated to 3′... [and] an excellent chronometer... " (Tupman 1883).

Beverly (1822–1907) came to New Zealand in 1856 and quickly activated his astronomical interests. In addition to comets he observed the 1882 transit of Venus and a total solar eclipse that was visible from New Zealand in 1885 (Campbell 2001; Orchiston 1998b).

The foregoing excerpts give some indication of the wealth of documentation available through the Tebbutt Letters, but they represent only a small sample, even for New Zealand. In all, the Tebbutt Letters contain 88 different items, from 17 different authors, that relate in one way or another to New Zealand astronomy. These are discussed in more detail in Orchiston 1985b.

3.3. Astronomical journals, 1853–1902

Variously referred to in the Mitchell Library shelf lists as "Astronomical Observations", "Diaries", "Journals" and a "Minute Book", these seventeen volumes mainly contain day-by-day journal entries from 1853

to 1902 of all things astronomical. They therefore provide a detailed account of Tebbutt's astronomical observations from the date of his very first glimpse of the Great Comet of 1853 through almost to his official retirement from observing at the end of 1903. But they do more than this, for they also include data on the Windsor Observatory, Tebbutt's telescopes and his other astronomical instruments; sky conditions; visitors to the Observatory; and its latitude and longitude (but see, also, Section 3.5 below). They also record his astronomically-motivated visits to Sydney.

Of particular interest are the journals dating between 1853 and 1861, since most of the observations recorded in them never made it into print. These were Tebbutt's 'apprenticeship years', when anything and everything celestial captivated him, and we see this reflected in these manuscripts. In addition to a search for Vulcan and observations of sunspots, meteors and fireballs, a transit of Mercury, solar and lunar eclipses, lunar occultations, Saturn, Jovian satellites, comets, the zodiacal light, double stars and variable stars, we find records of atmospheric phenomena (solar and lunar haloes, double rainbows and aurorae), and observations of the Sun and stars made in order to determine the latitude and longitude of the Peninsula Estate (for at this time there was no Windsor Observatory). Many drawings, particularly of sunspots, accompany the journal entries, but these and other renditions (particularly of comets) reveal that Tebbutt was no natural artist. But he was an avid observer, keen to learn proper observing techniques, and trial and error played a key role. For example, on 17 September 1855 he went to observe his very first lunar occultation, and "The star [8 Scorpii] was gradually approaching the limb, when my breath accidently entered the eyepiece of the telescope, and this of course rendered the star indistinct." (Tebbutt 1853–1859). By the time defogging had occurred the star was gone. As he perfected his observing and mathematical skills, Tebbutt also reassessed his potential targets, and decided to jettison some of the objects (like sunspots) that particularly took his fancy in these early formative years. The days of experimentation were over.

Once furnished with a proper astronomical telescope and observatory Tebbutt embarked on what can only be described as a prolific observing program, and although many of the observations recorded in his post-1863 journals found their way into print, lots of the detailed documentation, most of his field sketches, and some of his earliest experimental observations did not. For instance, Tebbutt (1873–1879) tells us that after looking unsuccessfully for Comet 6P/d'Arrest on 13

April 1877, he located the minor planet Vesta, and used the ring micrometer to obtain nine positional measurements (which were recorded in his journal). Minor planets only became an important part of Tebbutt's research repertoire nine years later, once he had access to the much larger clock-driven Grubb telescope.

Generally, Tebbutt's observations are presented neatly and clinically, but every so often an entry appears that reveals his deep love of astronomy and his fascination for the night sky. Thus, 11 May 1864 was "A brilliant night, the milky-way beautifully white against the dark background of the sky." (Tebbutt 1864–1869), while on the evening of 22 September 1879 he was enthralled by Jupiter's appearance:

> "In addition to the two long dusky red equatorial belts, there was another large oblong and bright pink patch below or *apparently* north of the equator. It appeared to be edged with white, of a whiter colour than the general ground of the disc. The general ground I regard as a light yellow. At this time the planet's disc presented one of the most beautiful views I have ever seen of it." (Tebbutt 1879–1881).

The following year, the lunar eclipse of 22–23 June 1880 was reportedly "... very interesting owing to her [the Moon] being at the time in the eastern branch of the Milky Way." (*ibid.*), and on the morning of 26 May 1881,

> "While looking for the comet I was surprised by one of the most charming sights I have ever beheld. This was the group just above the eastern horizon comprising the moon, now a crescent, and Venus, Jupiter and Saturn. All three of the planets were very bright in the clear morning sky, more particularly Venus which shone with extraordinary brilliancy. A white fog creeping along the low points, but not rising to the horizon, set off the spectacle to great advantage." (*ibid.*).

Accompanying this account is a field sketch. In another example, on 2 August 1882 Tebbutt (1882–1884) noted that "The contrast between the colours of the planets as seen in the comet eyepiece was very marked and beautiful, Mars was fiery red while Venus was beautifully white."

Tebbutt's first astronomical acquisitions were a sextant and a copy of Norie's *Epitome of Navigation*, and his 1853–1859 journal describes

the associated coach trip to Sydney on 23 September 1853. The sextant was a valued supplement to the marine telescope made available by his father, while Norie's volume marked the start of what would later grow into a major research and reference library. From this date, there are accounts as each new instrument is acquired, but particularly invaluable is a 13-page overview at the start of the 1879–1881 journal, with details of all three Windsor Observatory buildings, the sextant and artificial horizon, the marine telescope, the Jones and Cooke refractors, both transit telescopes, and chronometer, a microscope, and the various meteorological instruments.

Only occasionally do the journal entries reflect the obvious affection that Tebbutt held for the instruments that brought him such international renown, but this certainly comes through when he describes the Jones refractor in the Introduction to his 1890–1892 journal:

> "Since the acquisition of the 4½ equatorial it [the Jones refractor] has been restored to its tripod stand and frequently employed in observations of variable stars and in examination of the moon's dark limb for probably occultations. It is to me a very interesting instrument as it is associated with my earliest efforts at astronomical observation."

By this time the Jones telescope had been with him for nearly thirty years, and although surpassed in aperture by the Cooke and Grubb refractors and inappropriate for most of the observing programs that then held sway at Windsor Observatory, Tebbutt still found a way for it to make a meaningful research contribution.

From time to time evening visitors came to Windsor Observatory, and in his early years Tebbutt welcomed them, but with the passage of the years he became increasingly less tolerant of the requisite loss of valuable observing time and the danger that strangers could pose to his delicate scientific instruments. Compare, for example, the following journal entries, which date to 19 September 1864 and 15 July 1891, respectively:

> "I did not observe the comet last night [i.e. 18 September], owing to the Rev John Mosley being at the Observatory. I showed him the comet, which was faint, Jupiter, the double star α Centauri, and other objects. He was much gratified with the visit." (Tebbutt 1864–1869).

> "Last evening a Windsor gentleman came to the Observatory according to appointment to see the moon, but instead of bringing only another visitor with him as stipulated he brought three others, making five visitors in all. The consequence was that my small round equatorial chamber was well filled. The accident which happened to me on the 8th instant and is recorded above [the spider hairs on the micrometer eyepiece were broken] was due to the agitation produced by a visitor at unseasonable hours, and now again last evening I had the misfortune to break a small tube which holds the square-bar micrometer ... and the micrometer fell to the floor ... I endeavour to avoid visitors as much as possible [now], for I find there is nothing but ill luck in the reception of them. They come without five minutes preparation for what they wish to see, and go away just as edified as before their arrival." (Tebbutt 1890–1892).

In addition to visitors to Windsor Observatory, Tebbutt's observing journals also mention his visits to Sydney Observatory, and his other astronomical journeys to Sydney by coach or train, mostly to attend meetings or to purchase instruments. One interesting exception has a particularly historical ring to it. In his entry for 18 January 1868, Tebbutt reveals that he "...visited for the first time the ruins of the old Parramatta Observatory, erected by Sir Thomas Brisbane in the Domain. The old stone transit piers are in a tolerable state of preservation... I felt much pleasure in visiting a place so intimately associated with astronomical science." (Tebbutt 1864–1869).

Only occasionally do Tebbutt's rather clinical journal entries reveal something of his personality. His first published observations were of Comet 109P/Swift-Tuttle in 1862, and appeared in two different issues of *Astronomische Nachrichten.* On 23 June 1863 he received four issues of this journal, and recorded in his Diary: "No 1404 contains my <u>second</u> letter to the Editor on the subject of Comet II. He has styled me "<u>Director der Sternwarte zu Windsor in Neu-Süd-Wales</u>" which is very annoying, considering that my astronomical observatory is merely a <u>portable</u> one." (Tebbutt 1863; his underlining). Others might view this as an unintended compliment, but Tebbutt was a stickler for honesty and 'the truth'; as such, it was an indiscretion! Another all-too-brief glimpse of the 'inner man' is revealed in the fascinating journal entry for 7 August 1895 when we learn for the first time about Tebbutt's beloved night-time companion, 'Jacko':

> "Poor Jacko, my pet magpie and a remarkably intelligent bird, was unfortunately killed by one of the dogs... He was an exceedingly clever imitator, and my constant companion at the Observatory day and night for the past seven years. I buried him yesterday under the ladder which leads up to the maximum shade thermometer. On this ladder he was accustomed frequently to roost and when not asleep invariably saluted me on my passage to and fro between the main observatory and the round equatorial room. I was wonderfully attached to the poor bird and I feel his loss very keenly. Hence this little tribute to his memory." (Tebbutt 1894–1896).

This paints a picture of a lonely astronomer sharing his celestial vigils with a pet magpie!

3.4. Observational note books, 1862–1865, 1879–1882, 1884–1905

These little note books contain event timings, micrometric measurements, notes, descriptions and field sketches, all recorded 'live', while at the telescope. Most of these details were subsequently transferred to the astronomical journals, although some of the sketches and notes were not. The note books therefore contain some useful supplementary data for those researching specific aspects of Tebbutt's observing programs, particularly his cometary work.

3.5. Determination of latitude, 1882, and longitude, 1885–1887

Precise knowledge of the latitude and longitude were prerequisites for any nineteenth century observatory engaged in positional astronomy, and Windsor Observatory was no exception. Tebbutt was keen to determine both parameters right from the founding of the Observatory, but it was only with the construction of the more substantial brick building in 1879 (see Fig. 2) that he derived a figure for the latitude that was used throughout the remainder of his observing 'career'. This was $33°36'30''.8$ S, which compared favourably with the value obtained for the original Observatory building, $33°36'28''.9$ S (Tebbutt 1884). In the "Definitive Determination of Latitude, 1882" record lot there are two crudely bound bundles of papers that relate to this new latitude determination.

Whilst establishing latitude was a relatively straight-forward matter, there was considerable debate over the best way of determining the longitude of an observatory (e.g. see Challis 1879). Initially Tebbutt used lunar occultations to derive a figure of $10^h03^m21.81^s$E (see Tebbutt 1880), but between 1885 and 1887 he used two other methods, which gave slightly different results. One was the telegraphic exchange of time signals between his Observatory and Sydney and Melbourne Observatories, and the other involved physically transporting a Windsor Observatory chronometer to Sydney Observatory and comparing it with the time shown there. These two methods produced values of $10^h03^m20.11^s$ E and $10^h03^m20.21^s$ E, respectively, and relevant here are the six crudely-bound bundles of papers in the "Papers re Telegraphic Determination of Longitude..." record lot. As a matter of interest, a fourth longitude determination method, linking Windsor Observatory to the local trigonometric survey, gave a very similar result ($10^h03^m20.88^s$) when this was later attempted (see Tebbutt 1888).

By the end of the nineteenth century the latitude and longitude of Windsor Observatory were known with considerable precision, and this private establishment was able to join Melbourne and Sydney Observatories in providing the fundamental reference framework for all Australian astronomical observatories.

3.6. Extracts from periodicals etc.

This record lot includes extracts of various research papers (mainly about specific comets) that appeared in *Astronomische Nachrichten*, *Comptes Rendues des Sciences...*, *English Mechanic* and *Nature*, as well as two items about the computation of cometary orbits (something in which Tebbutt became particularly proficient), and one on the reduction of lunar occultations.

As indicated in Section 2, Tebbutt was responsible for forming a Corps of Comet Observers, Australia's first national astronomical group of any kind (see Orchiston 1982). This particular Tebbutt Collection record lot includes a 4-page document about the proposed *modus operandi* of the group, and is almost certainly a draft that Tebbutt sent A.B. Biggs for his evaluation and comment. Biggs was a noted Tebbutt protégé (see Orchiston 1985a), and apart from Tebbutt was the only other active member of this anachronistic short-lived group.

Still on the topic of astronomical groups and societies, two items of special interest in this record lot are the full texts of Tebbutt's Presidential addresses prepared for the Inaugural Meeting and the second Annual General Meeting of the New South Wales Branch of the

British Astronomical Association. These manuscripts run to 14.5 and 13 manuscript pages respectively, and contain a lot of useful information in that only 1.5–2 page summaries of them were published in the Association's *Journal* (see Reports of the Branches..., 1895; 1897). As its founding President, Tebbutt added international credibility and visibility to the Branch, and was one of those who was instrumental in seeing it develop rapidly during the early years (see Orchiston 1988b).

Finally, this record lot includes a fascinating 47.5-page manuscript about Christianity and astronomy. On 3 June 1909 Tebbutt wrote and initialled the following description on the first page of this document: "Rough Draft of a Lecture made some years ago, but not since utilized." For much of his life, Tebbutt was interested in the interplay between astronomy and religion, and sought to reconcile their sometimes disparate views. This was a theme upon which he occasionally lectured, and he even published a booklet on the topic (Tebbutt 1878).

3.7. Hot winds, 1862–1863; and meteorological observations, 1863–1913

The first of these record lots consists of an exercise book with detailed meteorological observations on successive days between 24 December 1862 and 14 January 1863, a period when Windsor experienced prolonged hot winds. Extreme maximum shade temperatures were recorded on three different days: 107°.0 Fahrenheit on December 24, 113°.4 on January 5 and 106°.7 on January 9. These observations came straight after Tebbutt acquired a range of instruments and set up a fully-equipped meteorological station. At the end of January 1863 he submitted his first monthly meteorological report (Russell 1863), and from this date he continued to provide regular reports to Sydney Observatory and to Windsor district and Sydney newspapers through until 1898, when a curtailed meteorological program was adopted (and continued up until his death in 1916).

The thirteen bound volumes making up the record lot, "Meteorological Observations, 1863–1913", contain the various observations made by Tebbutt at the Windsor Observatory. Not only were these summarised in his monthly reports, but at his own expense he also published eight different monographs reporting on this work (Tebbutt 1868, 1874, 1877, 1882, 1886, 1891, 1898b, 1916). These monographs, which were widely distributed within Australia and overseas, collectively total 389 pages and provide a document of the weather and flooding at Windsor for more than half a century. In addition, Tebbutt published

research papers on Australian storms and Saxby's weather-prediction model, and a series of newspaper articles on periodicity in local rainfall.

It is apparent that in addition to his outstanding astronomical record, John Tebbutt deserves to be recognised as a pioneer of Australian meteorology (Todd 1893), and that a separate detailed study of his overall contribution in this important scientific field is long overdue.

3.8. Catalogue of the Windsor Observatory library

One of the reasons for Tebbutt's success as a researcher and populariser was that he could fall back on an outstanding private research and reference library, and the "Catalogue of the Observatory Library" record lot documents this. A perusal of the entries reveals a goodly selection of books and monographs, runs of journals, and an extensive collection of reprints, some of which were unavailable elsewhere in New South Wales – including at Sydney Observatory (see, e.g., Knibbs 1900). In order to publicise the Windsor Observatory Library and at the same time provide appropriate acknowledgement for donors, Tebbutt (1887: 47–74) outlined the Library holdings in his *History and Description of Mr. Tebbutt's Observatory...*, and each year thereafter all new acquisitions were listed in successive *Annual Reports* of the Windsor Observatory.

It was partly these *Annual Reports* that allowed Tebbutt to successfully grow his library, as these little 19–33 page booklets, other books and booklets that he from time to time published, and reprints of his papers formed the basis of an elaborate international publications exchange network. By the end of the nineteenth century this involved 168 different donors in 33 countries, and most of the world's foremost observatories were supplying Windsor Observatory with gratis publications – which says a great deal about Tebbutt's international reputation. In addition to private and professional observatories, he received exchanges and gifts from various government departments, universities, scientific societies and individuals.

3.9. Other records

The three remaining record lots, "Calculations; Reduction of observations, 1853–1910", "Instrumental determinations, 1882–1901" and "Values of wire of transit instrument, 1885–1903" are self-explanatory, and hardly deserve comment here. Many of the reduced times or positions contained in the first record lot appeared in Tebbutt's publications, including newspaper articles that appeared before he began publishing in local and international journals. Meanwhile, some of the

data in the second and third record lots were reproduced in his *History and Description of Mr. Tebbutt's Observatory...* (Tebbutt 1887) and in the *Annual Reports* that he published as little booklets between 1888 and 1903 (inclusive).

4. The Missing Records

Even a cursory examination of the surviving Tebbutt manuscripts in the Mitchell Library reveals that there are a number of curious gaps in the collection. One of the glaring omissions relates to copies of Tebbutt's outward letters (to which many of the inward letters relate), and their whereabouts has long remained a mystery. Given his professional approach to record-keeping and his methodical nature, it is reasonable to suppose that Tebbutt maintained an outward letter file, and the following "Memorandum" in the Mitchell Library puts the matter beyond dispute:

> "The M.S. found herewith contains the draft of Results prepared at the request of Professor Auwers of Berlin, as per his letter of May 31st 1886. A clean copy of this draft was forwarded by post yesterday to his address. *See Letter Book, page 44.*" (Tebbutt n.d.; my italics).

This memorandum is dated 3 November 1886, and at that time Auwers was investigating the longitude of the Windsor Observatory and had asked Tebbutt to send him some lunar occultation observations from the 1860s.

If Tebbutt's outward Letter Books had survived through to the year of his death they would have run to many volumes, and like the inward letters would have occupied several linear metres of bookshelf space. Checks with Mitchell Library staff indicate that all of the donated Tebbutt manuscript material has definitely been catalogued, and that the 'missing' volumes are not languishing somewhere in the basement, unrecognised and long forgotten.

Given their importance in the overall scheme of things, it is unlikely that the outward letter books would have been retained by the family in 1917 had they survived. This suggests that most if not all of these books did not survive, and a number of possible explanations come to mind. Floods were a comparatively common occurrence at Windsor during the nineteenth and early twentieth centuries and impacted directly on the Windsor Observatory (see Table 3), but it is

unlikely that the missing volumes were destroyed during one or more of these since all of the other records apparently survived these natural disasters. Besides, Tebbutt (1908) makes no specific mention of the loss of any such records in his *Astronomical Memoirs*, which was written in 1907. Nor is there any reference to such a loss in his Annual Reports, in any of the inward letters, or in newspaper articles and reports.

However, several letters do refer to another catastrophe: a fire that occurred in December 1897. A news item in the 11 December issue of the *Daily Telegraph* reports:

> "A fire broke out in the storeroom at Mr. John Tebbutt's Windsor Observatory early this morning, the building and contents being consumed. But for the exertions of many hands the main buildings would have caught. The walls were considerably charred as it was." (Fire at Windsor 1897).

The specific wording of this account, and a similar one in the *Sydney Morning Herald*, give the impression that the Windsor Observatory itself and its entire contents were destroyed, and among others Brooks (1897), Gale (1897), Knibbs (1897), and Merfield (1897), four well-known Sydney astronomers, immediately wrote expressing their concerns and dismay. However, a letter from Dick (1897) indicates that this fire was actually located in one of the free-standing buildings adjacent to the Observatory. Thanks to a map of the Peninsula Estate buildings produced on page 120 in the 1986 reprinting of *Astronomical Memoirs* we can identify this storeroom, for this shows a rectangular building, "H", near to the kitchen wing of the homestead and described as "Site of granary & storeroom destroyed by fire Dec 1897 (now rebuilt)."

I believe that all of the outward Letter Books, except the one current at that time, were housed in this store room in 1897 and were destroyed or damaged beyond repair in the course of the fire. Regrettably, there is no mention of the fire in Tebbutt's *Annual Reports* for 1897 or 1898 (Tebbutt 1898a, 1899) or in his *Astronomical Memoirs* (Tebbutt 1908), and there are no entries at all in his Journal (Tebbutt 1896–1898) between the dates of 5 and 23 December 1897, but some of the Tebbutt Collection items in the Mitchell Library do have water damage (e.g. A3779), while others display fire damage or have a distinctly smoky smell.

This scenario would explain the disappearance of the Letter Books pre-dating 1898, but what of those letters written by Tebbutt between

that date and his death in 1916? In 1992, the present owner of the property, John Halley Tebbutt (a great grandson of the astronomer), informed me (pers. comm.) that a search of the various Peninsula Estate buildings at one time produced what appears to have been a single Letter Book (from his recollection it contained pages of carbon copies of letters in John Tebbutt's distinctive writing). Unfortunately, he was unable to locate this at the time of my visit, or on subsequent ones. I believe that when this document eventually reappears it will prove to be one of the missing 'post-fire' Letter Books.

There are also a number of other obvious gaps in the Mitchell Library's Tebbutt Collection. We know that Tebbutt continued to observe almost up to the time of his death and that he processed these observations (e.g. Tebbutt 1905–1915) and published them, but there is no manuscript journal summarizing his observations after 1903, even though it is highly likely that one was maintained. Nor is there an 'Observational Notebook' for the period 1906–1915, although Tebbutt's post-retirement publications would indicate that one was definitely kept. The other glaring inconsistency is the absence of any observational notebooks for the interval 1866–1878. We know that notebooks were kept at this time since observations were made, reduced and published, and a journal was maintained.

I believe that these 'missing' manuscripts were retained by the Tebbutt family when the remainder of the Tebbutt Collection went to the Mitchell Library (perhaps because the family planned to write about their illustrious relative, and most of these documents built on the autobiography that Tebbutt had published in 1908), but were subsequently destroyed. Two possible scenarios come to mind. When I first visited the Windsor Observatory, in 1959, the Peninsula Estate was owned by Bruce Tebbutt (1904–1963), a grandson of the astronomer, and he kept various historic memorabilia in a large safe in the cottage in which he lived (at that time the 1843 Tebbutt homestead and the 1879 observatory building were rented out). Soon after his death in 1963 this safe was opened for the first time in a great many years and was found to be full of water from the 1961 flood – and possibly from an earlier flood or floods. Apart from some coins and rings, and the 1905 Jackson-Gwilt medal and a silver medal that Tebbutt received in connection with the 1867 Paris Universal Exhibition, this safe contained nothing else but "black slime" (J.H. Tebbutt, pers. comm., 1996) which could represent the decayed remains of the missing manuscripts. Alternatively, in 1959 I discovered a large assemblage of books (but mainly on topics other than astronomy), assorted papers, and various astronom-

Table 3. Major floods recorded on South Creek, 1857–1915.*

Year	Date of Maximum	Height (m)	Comments
1857	July 29	9.8	
	August 22	11.3	Very destructive flood
1860	April 29–30	11.2	Calamitous flood
	July 26	10.5	Destructive flood
	November 19	10.8	Calamitous flood
1864	June 13	14.4	Highest flood for many years; Observatory transit room floor 54.8cm above the flood level.
	July 16	10.9	
1867	June 23	19.1	Highest flood in recorded history; water was 4.1m deep on the floor of the Observatory transit room.
1868	February 18	8.9	
1869	May 9	11.1	
1870	April 28	13.5	
	May 13–14	10.6	
1871	April 30	9.5	
	May 2	11.1	
1873	February 26–27	12.5	
1875	June 7	11.7	
1877	May 2–3	9.1	
1879	September 11	13.0	
	September 17	10.4	
1889	May 29	11.6	
1890	March 13	11.7	
	March 26	10.3	
1891	June 26	10.8	
1894	March 23	9.7	
1895	January 24	9.3	
1898	February 15–16	9.7	
1900	July 7	14.1	Third highest flood of past 60 years; threatened Observatory buildings.
1904	July 12	12.2	

*Based on data published in Tebbutt 1877, 1882, 1886, 1891, 1898b, and 1916.

ical items (e.g. copies of *Annual Reports*, *Astronomical Memoirs* and meteorological monographs, and reprints of research papers) that had been dumped in the 1894 observatory building. They were not systematically grouped or stored, and many items were in very poor condition, with abundant evidence of silverfish and water damage. In addition, much paper-based material had disintegrated to the point where it was totally unrecognizable and literally fell to pieces if touched. It is quite

possible that some or all of the 'missing manuscripts' were among these items.

5. Concluding Remarks

We must count ourselves fortunate that the Tebbutt Collection is located in the Mitchell Library, one of Australia's foremost archival repositories. As such, it is cared for by well-trained staff, and stored in facilities that reflect the best internationally-accepted standards of preventative conservation. Meanwhile, if remedial action is called for through accidents or excessive use of the Collection by researchers, the Mitchell Librarian can call on the services of the State Library's Conservation Department. It is reassuring to know that the future of the Collection is secure.

On the other hand, the research potential of the Collection has yet to be optimised. The inward letters will only be effectively utilised as data-sources on Australian and non-Australian astronomical history when master lists of the different letters – and more importantly their contents – are available to scholars. Similarly, Tebbutt's observational records contain invaluable data and diagrams that were not included in his numerous publications, and it is only when detailed descriptions of the contents of all of the logs, journals, diaries and note books have been published that the full research value of this corpus of archives will be realised (even though some useful case-studies, incorporating such data, have already been published – e.g. see Orchiston 1998a, 1999a, 2000). The Tebbutt Collection also contains a rich history of Windsor meteorology, extending over more than half a century, and this invaluable data-set will only be properly probed and utilised when the story of Tebbutt's role as a pioneering Australian meteorologist is written. But in order to do this effectively, and for many other Tebbutt case studies, it would help immeasurably if we could access Tebbutt's outward letters. Since his file copies cannot be found, this will involve an extensive and expensive survey of many overseas repositories in a quest for the originals. Some of these (such as those in the RAS archives) have already been examined, but much remains to be done.

John Tebbutt has been described as "The undisputed jewel in the crown of Australian amateur astronomy" (Haynes et al., 1996: 115), and the Mitchell Library's Tebbutt Collection will long remain a vital resource for those researching nineteenth century Australian astronomy.

Acknowledgements

I am grateful to John Halley Tebbutt for information about his illustrious ancestor and the Tebbutt Collection, to staff at the Mitchell Library for their assistance and permission to publish Fig. 5, to Wayne Hammond (Williams College) for kindly supplying Fig. 3, and to Paul Angus (Wellington) and the Institute of Geological and Nuclear Sciences (Wellington) for kindly providing Figs. 4 and 6.

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ASTRONOMICAL HERITAGES: Astronomical Archives and Historic Transits of Venus
Journal of Astronomical Data, Vol. 10, 7, 2004
Christiaan Sterken, Hilmar W. Duerbeck, eds.

The Lorenzoni-Tacchini Correspondence at Padova Observatory Archives: the "True" History of Italian Astronomy of the Second Half of the Nineteenth Century

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Abstract

The correspondence between Giuseppe Lorenzoni and Pietro Tacchini covers the period from 1870 to 1905. Two hundred and ninety original letters written by Tacchini to Lorenzoni and 177 rough copies of letters by Lorenzoni to Tacchini are preserved at the Padova Observatory Archives. Their friendship, which started in 1870 during the expedition to the total solar eclipse in Sicily, as well as their astronomical ability, were of great importance for many events in Italian astronomy during the second half of the 19th century. We are able to gather from this correspondence the following things: 1) the hard work that was put into the founding of the 'Società degli Spettroscopisti Italiani' which succeeded in 1871 mainly thanks to the willingness of three astronomers, Secchi, Tacchini and Lorenzoni; 2) important details about the preparation for the Italian party to India to observe the transit of Venus in 1874; 3) the role of both Lorenzoni and the workshop of the Observatory of Padova in successfully making two large equatorial mountings for the new Catania Observatory and the Bellini Observatory on Mount Etna, and later those for the Italian Observatories of Turin, 'Collegio Romano' in Rome, and Arcetri in Florence.

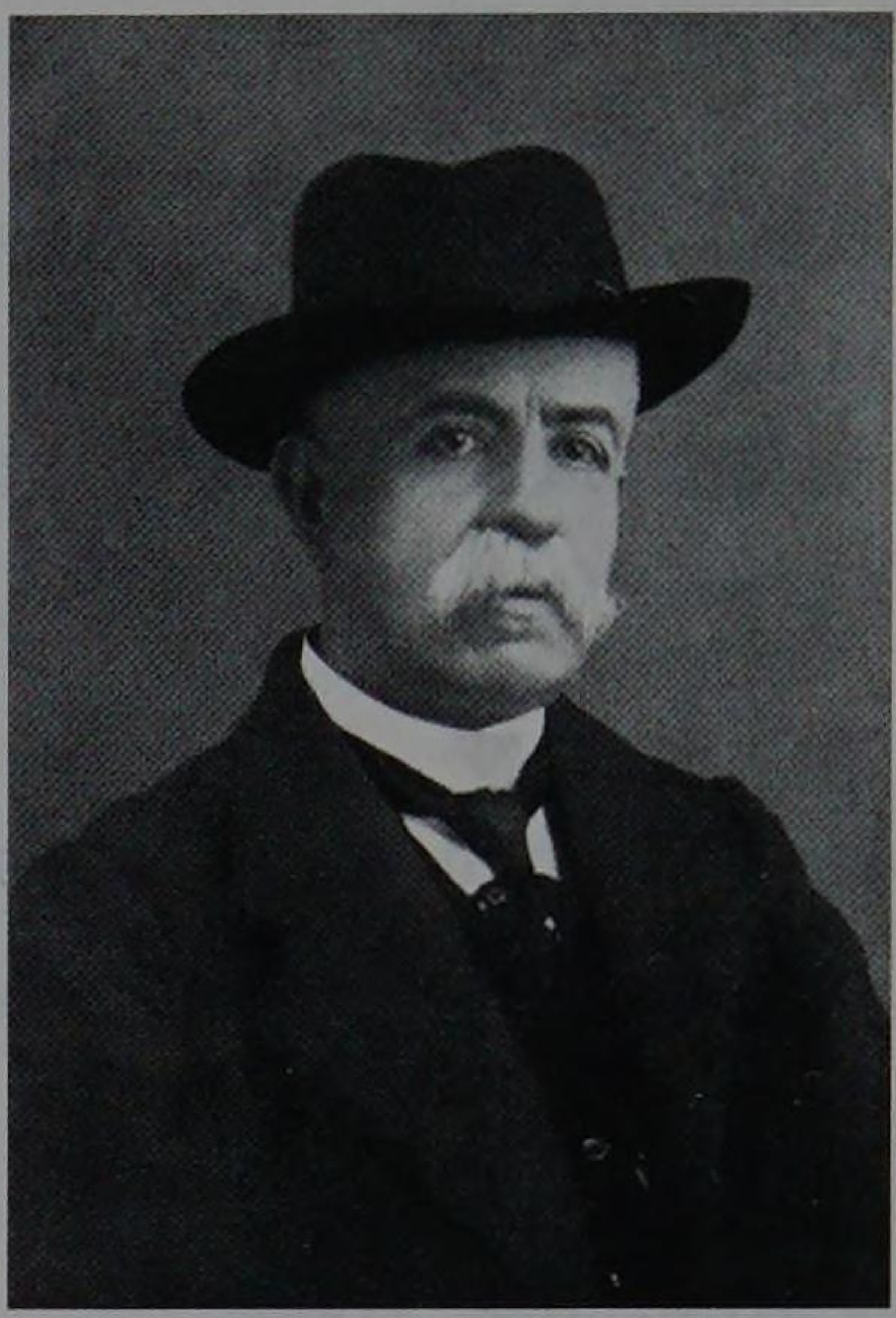


Figure 1. Gregorio Ricci-Curbastro (Padova Observatory Archives).

1. Introduction

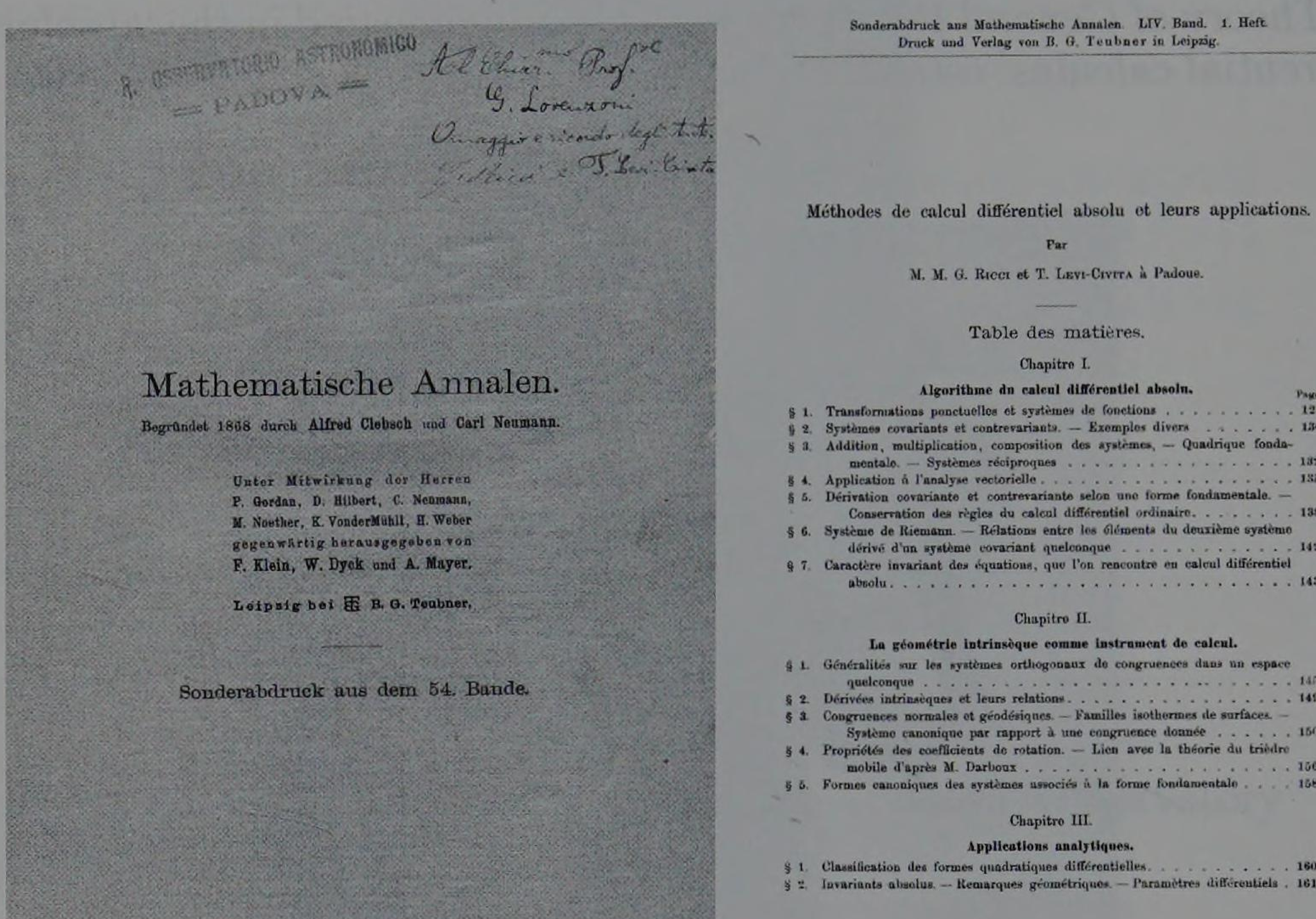
Nobody knows why Gregorio Ricci-Curbastro (1853–1925) – better known as Ricci – the famous mathematics professor at the Padova University (Fig. 1), kept the letters that Giuseppe Lorenzoni (1843–1914) had received from Italian astronomers, especially from Pietro Tacchini (1838–1905) and Giovanni Virgilio Schiaparelli (1835–1910), and his rough copies of letters to them.

At the end of the World War II, Giorgio Ricci-Curbastro, Gregorio's son, who lived in Faenza, sent a thick parcel of these letters to Giovanni Silva (1882–1957), sixth director of the Padova Astronomical Observatory. It seems that a great part of these letters was destroyed during the war. Silva's opinion was that Ricci, before his unexpected death in 1925, took part in a commission together with Tullio Levi-Civita (1873–1941), Antonio Maria Antoniazzi (1872–1926) and others, with the task of publishing the most important papers and a detailed biography of Lorenzoni, beloved director of the Padova Observatory. Ricci had been Lorenzoni's colleague at Padova University, Levi-Civita and Antoniazzi had been pupils and later colleagues of both of them, while Silva had been a pupil and colleague of the latter ones. It is worth mentioning that Ricci and Levi-Civita are the two famous mathematicians of whom Einstein wrote: *"The mathematical tools necessary for*

the Theory of General Relativity were already prepared in the 'absolute differential calculus' established as a system by Ricci and Levi-Civita."

Figure 2. From left to right: I. Galmozzi, G. Legrenzi and Tullio Levi-Civita (Padova Astronomical Observatory Historical Archives).

Documents preserved at the Observatory Archives prove the strong relationship between all the above-mentioned people: the funny picture which Levi-Civita gave to Lorenzoni when he got his degree in mathematics in 1894 (Fig. 2), for example, and all the papers published by Levi-Civita with autograph dedications to Lorenzoni (Fig. 3), then to Antoniazzi (Fig. 4), and finally to Silva (Fig. 5), all of them subsequent directors of the Astronomical Observatory of Padova.



R. OSSERVATORIO ASTRONOMICO
— PADOVA —

Al Chiar.mo Prof.re
G. Lorenzoni
Omaggio e ricordo degli Aut.
G. Ricci e T. Levi-Civita

Mathematische Annalen.

Begründet 1868 durch Alfred Clebsch und Carl Neumann.

Unter Mitwirkung der Herren
P. Gordan, D. Hilbert, C. Neumann,
M. Noether, K. VonderMühll, H. Weber
gegenwärtig herausgegeben von
F. Klein, W. Dyck und A. Mayer.

Leipzig bei B. G. Teubner.

Sonderabdruck aus dem 54. Bande.

Sonderabdruck aus Mathematische Annalen. LIV. Band. 1. Heft.
Druck und Verlag von B. G. Teubner in Leipzig.

Méthodes de calcul différentiel absolu et leurs applications.

Par

M. M. G. Ricci et T. Levi-Civita à Padoue.

Table des matières.

Chapitre I.

Algorithme du calcul différentiel absolu.

Chapitre II.

La géométrie intrinsèque comme instrument de calcul.

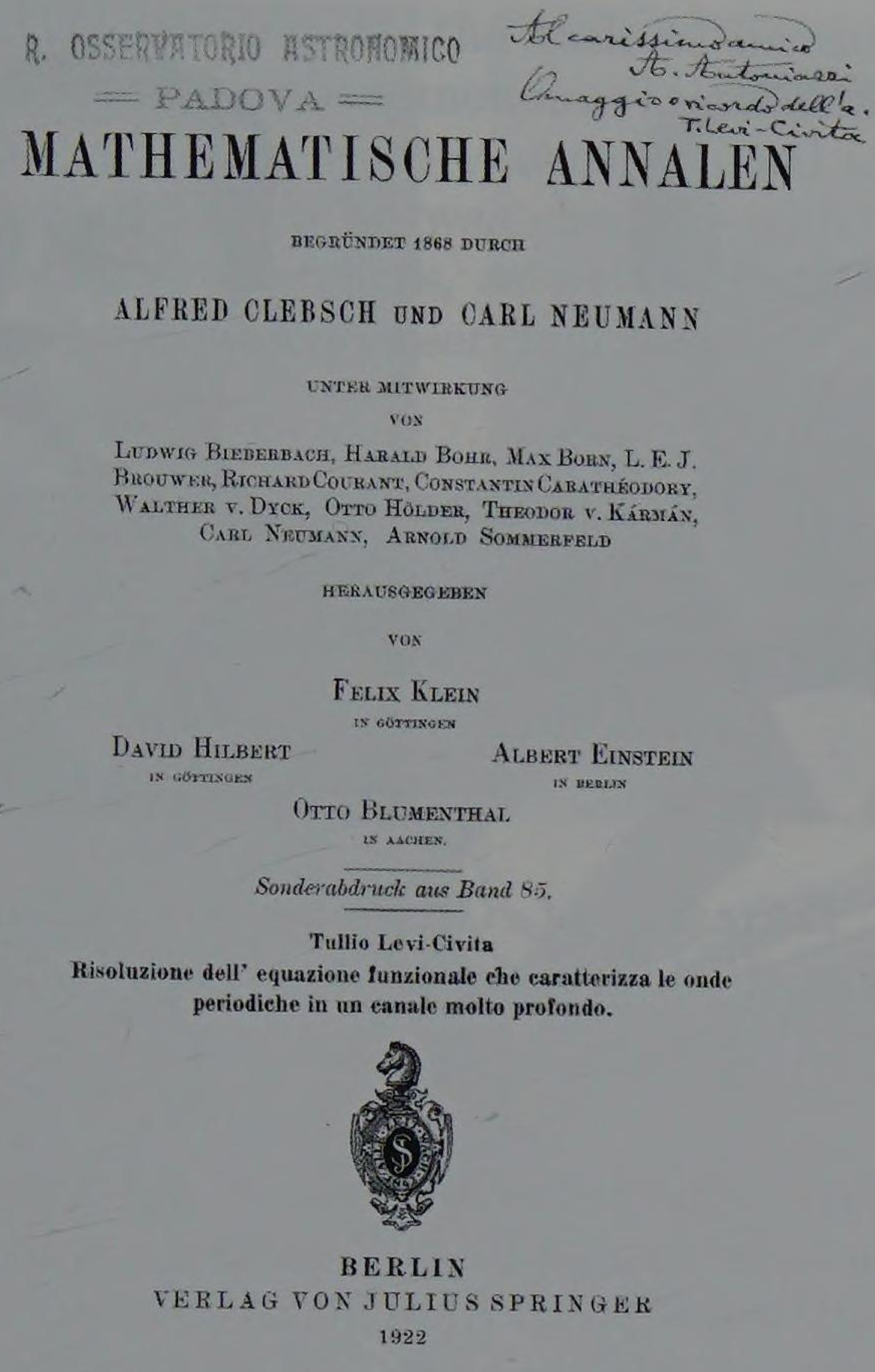
Chapitre III.

Applications analytiques.

Figure 3. *Left:* Cover with Ricci's and Levi-Civita's autograph dedication to Lorenzoni. *Right:* summary of their paper on differential calculus.

The correspondence between Giuseppe Lorenzoni, astronomer at the Padova Observatory, and Pietro Tacchini from Modena (Fig. 6), covers the period from 1870 to 1905. The friendship between the two astronomers began during the party to observe the total solar eclipse of 1870. It "suffered from some unfeeling periods [as Lorenzoni wrote at Tacchini's unexpected death in 1905] but it never failed".

Two hundred and ninety original letters written by Tacchini to Lorenzoni and 177 rough copies of letters by Lorenzoni to Tacchini, are preserved at the Padova Observatory Archives. These letters focus on three important events: the first one concerns the total solar eclipse of December 22, 1870, the second one the 1874 transit of Venus, the last one, the construction of large equatorial mountings for Italian telescopes.



R. OSSERVATORIO ASTRONOMICO
= PADOVA =

Al carissimo amico
A. Antoniazzi
omaggio e ricordo dell'a.
T. Levi-Civita

MATHEMATISCHE ANNALEN

BEGRÜNDET 1868 DURCH

ALFRED CLEBSCH UND CARL NEUMANN

UNTER MITWIRKUNG
VON

LUDWIG BIEBERBACH, HARALD BOHR, MAX BORN, L. E. J. BROUWER, RICHARD COURANT, CONSTANTIN CARATHÉODORY, WALTHER V. DYCK, OTTO HÖLDER, THEODOR V. KÁRMÁN, CARL NEUMANN, ARNOLD SOMMERFELD

HERAUSGEGEBEN
VON

FELIX KLEIN
IN GÖTTINGEN

DAVID HILBERT
IN GÖTTINGEN

ALBERT EINSTEIN
IN BERLIN

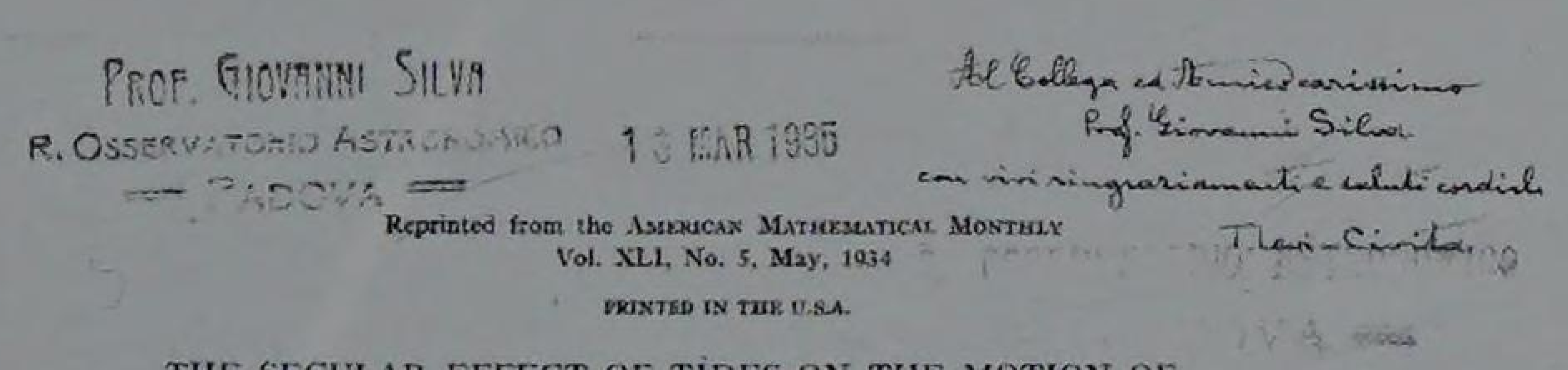
OTTO BLUMENTHAL
IN AACHEN.

Sonderabdruck aus Band 85.

Tullio Levi-Civita
Risoluzione dell' equazione funzionale che caratterizza le onde periodiche in un canale molto profondo.

BERLIN
VERLAG VON JULIUS SPRINGER
1922

Figure 4. Levi-Civita's autograph dedication to Antoniazzi (Padova Astronomical Observatory Historical Archives).



PROF. GIOVANNI SILVA
R. OSSERVATORIO ASTRONOMICO
= PADOVA =
13 MAR 1935

Al Collega ed Amico carissimo
Prof. Giovanni Silva
con vivi ringraziamenti e saluti cordiali
T. Levi-Civita

Reprinted from the AMERICAN MATHEMATICAL MONTHLY
Vol. XLI, No. 5, May, 1934

PRINTED IN THE U.S.A.

THE SECULAR EFFECT OF TIDES ON THE MOTION OF PLANETARY SYSTEMS

By TULLIO LEVI-CIVITA, University of Rome

Figure 5. Levi-Civita's autograph dedication to Silva (Padova Astronomical Observatory Historical Archives).

2. The Total Solar Eclipse of December 22, 1870

The phenomenon was observable in its totality in Spain, Sicily, Africa and along the Mediterranean coast. On July 1, 1869, the King of Italy, Vittorio Emanuele II, issued a decree to nominate a commission with

Figure 6. Portraits of Giuseppe Lorenzoni (left) and Pietro Tacchini (Padova Astronomical Observatory Historical Archives).

the task of carrying out studies of the eclipse. All directors of the Italian observatories (Gaetano Cacciatore of Palermo, Annibale De Gasparis of Naples, Giambattista Donati of Florence, Giovanni Santini of Padova, Giovanni Schiaparelli of Milan) took part in the commission. The 82-year-old Giovanni Santini (1787–1877) was appointed president of the Commission by the Minister of Education. In this way, the Commission planned the first scientific mission of the new Kingdom of Italy (Pigatto 1998). Six fundamental objectives had to be pursued:

1. determine height, colour, luminous intensity and spectrum of the chromosphere;
2. examine the structure of the prominences and their spectrum;
3. examine the spectrum of the corona and the polarisation of its light;
4. observe the bright plumes, their size, spectrum and relation to the position of prominences;
5. observe the first and last contact of the Moon with the Sun;
6. take photographs of the Sun during eclipse.

This ambitious program demonstrates the high level in astrophysical studies of the Sun in Italy, thanks in particular to Angelo Secchi (1818–1878), a very pioneer of modern astrophysics. Because of his old age,

Santini entrusted Cacciatore with the task of investigating the best places where to observe the phenomenon. Tacchini, at that time astronomer at the Palermo Observatory, accompanied Cacciatore on his journey to eastern Sicily, then he was charged with the task of getting ready lodgings for astronomers, as well as huts and supports for instruments, in the two chosen observing locations – Terranova and Augusta.

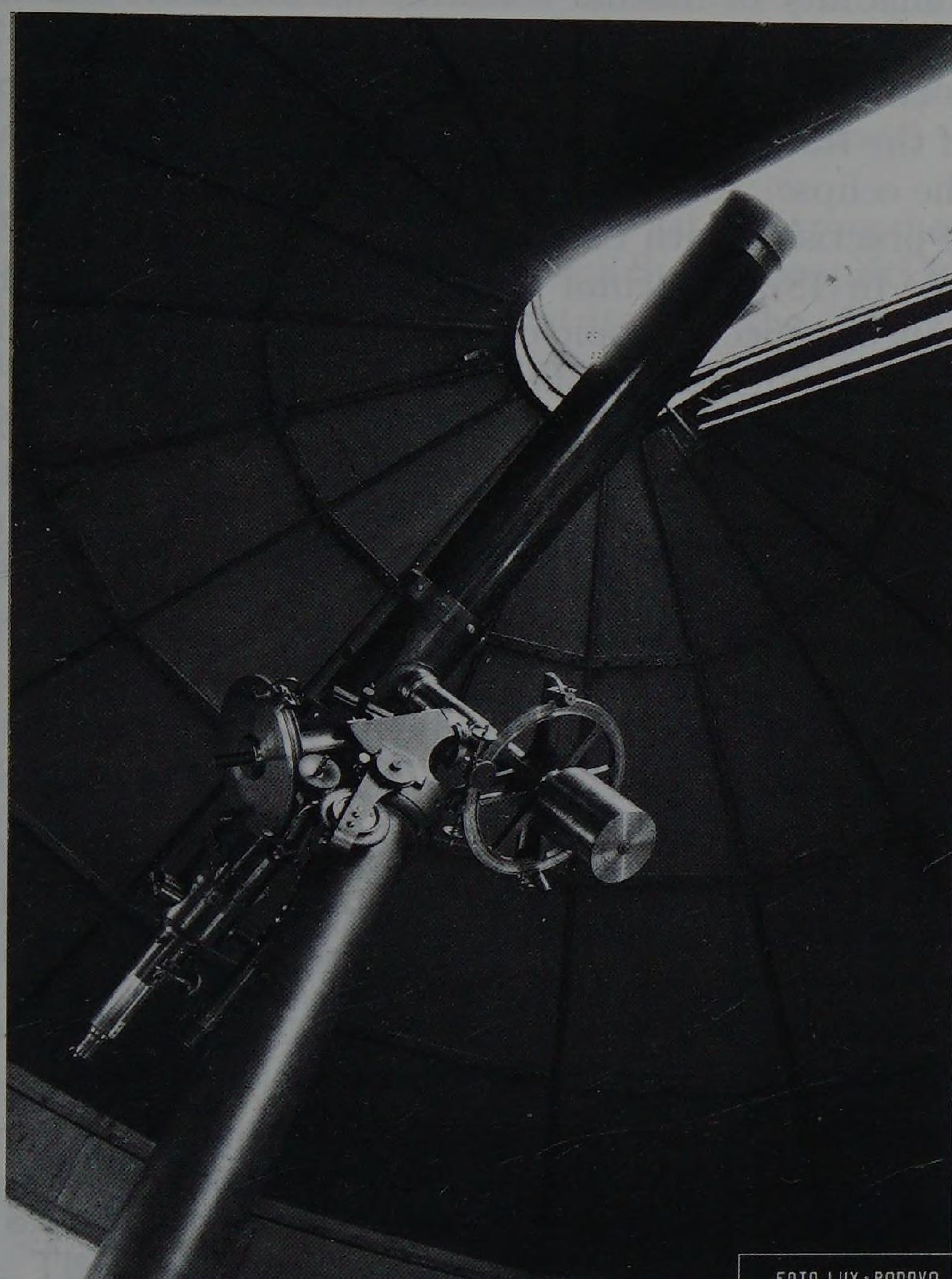


Figure 7. The Starke-Merz equatorial refractor (117-mm aperture) in its small dome at Padova Observatory (Padova Observatory Archives).

Tacchini's and Lorenzoni's first letters deal with the instruments that Padova Observatory had to send to Sicily for the eclipse, i.e. the

Starke-Merz equatorial refractor (117-mm aperture, 1.65-m focal length; Fig. 7), the Hofmann spectroscope and the Repsold universal instrument (Tacchini 1870; Lorenzoni 1870). The two astronomers had to use in collaboration the equatorial with the spectroscope mounted on it to observe the solar prominences and their spectrum.

The observations of the total eclipse yielded poor results because of the variable weather. In addition, unpleasant misunderstandings about the reliability of mutual scientific results arose among the astronomers of the two stations. As is apparent from the 1871 letters between the two friends, this is one of the reasons why the report (Santini 1872) of the Italian Commission was published only more than one year after the eclipse. Anyway, the eclipse gave the two friends the opportunity of practising with the spectroscopic observations of the solar prominences. In 1871 Tacchini suggested to Lorenzoni to make and draw simultaneous spectroscopic observations of the solar prominences in order to compare the results of their different spectroscopes (Tacchini 1871a). As a matter of fact, since 1868 Pierre J.C. Janssen (1824–1907) and Norman J. Lockyer (1836–1920) had invented a method to observe the prominences outside eclipse, it was possible to perform such observations on a daily basis. Tacchini suggested to Father Angelo Secchi to do the same; the Jesuit adhered immediately to these observations (Tacchini 1871b), at the same time he proposed to found a society in order to co-ordinate the spectroscopic solar observations among all Italian observatories. Tacchini wrote immediately to Lorenzoni:

> "Secchi... suggests to found a society in order to observe the Sun: It seems to me a good idea, and I hope you will take part in it. To this aim, a meeting should be organized in Rome next October in order to plan what to do." (Tacchini 1871c).

Tacchini took care of contacting Italian astronomers, but Secchi's idea didn't move them to enthusiasm. On September 13, Tacchini (1871d) wrote to Lorenzoni:

> "Our Society is shaky. Even if you are not coming [to Rome], you promised to be ready to work. Those of Naples say that they can't be involved at this moment, but Nobile is willing to take action when it will be established... Donati is against this project, for he states to be not convinced that everybody has to study prominences... Respighi didn't reply, so I think he wouldn't dare to take part in the Society.

> From Milan no reply. So we are three of us, me, you and Secchi."

Lorenzoni (1871) replied:

> "I'm sorry but not surprised to hear the negative results of your doings about the foundation of the Italian Society to study the solar prominences. I explain this fact to myself with the irreducible repugnance that many people have to play the role of satellites when they believe to be able to play, with or without reason, that of the main star."

Nonetheless, thanks to the willingness of the three astronomers – Secchi, Tacchini and Lorenzoni – the 'Società degli Spettroscopisti Italiani' was founded in November. In 1872, the first issue of the "Memorie" of the new Society, the first astrophysical journal in the world, was published. The first papers were by Lorenzoni, Secchi and Tacchini, obviously.

3. Preparing the Transit of Venus Party

Tacchini is to be considered the true promotor of the Italian party to India (Pigatto & Zanini 2001). However, this expedition succeeded also thanks to Lorenzoni, to his advanced knowledge of astronomical instruments that Santini, his teacher, had transferred to him, and the traditional skill of the mechanics at the Padova Observatory workshop. All the telescopes to be used for the observations were prepared, improved, modified at the Padova Observatory workshop under Lorenzoni's supervision. Before the packing and shipping to India, all telescopes were mounted in the "Sala delle Figure" at the top of the Observatory, in order to make and send a picture to the Italian ministers. Antonio Abetti, the young astronomer assistant to Lorenzoni at the Padova Observatory, took part in the Venus party. The letters he wrote to Lorenzoni during the expedition are included among the Lorenzoni-Tacchini correspondence. These letters give an interesting and amusing report about the long and adventurous journey from Venice to Alessandria in Egypt, from Alessandria to Suez by train, from Suez to Bombay, from Bombay to Muddapur by train, where our astronomers observed the transit of Venus.

The history started when the French astronomer Janssen wrote to Tacchini asking him about an eventual support of the Italian government to a transit expedition. This fact spurred Tacchini to write a

report to the Minister of Public Education, who gave him a positive answer after two months, when the Minister had learned that the Russians had asked Tacchini, or Secchi and Lorenzoni, to join them in a transit expedition to Egypt (Tacchini 1873a). In August 1873, Tacchini wrote letters to all the Italian astronomers asking them to agree to an Italian transit expedition. Only Secchi and Alessandro Dorna, director of Turin Observatory, agreed to take part in the Venus party. Lorenzoni couldn't take part in it for he had to provide all the duties of direction because of Santini's old age. He wrote to Tacchini that Antonio Abetti would take part in the mission, and the equatorial refractor, already used in Sicily, could be prepared for observations (Lorenzoni 1873). On December 25, 1873, Tacchini (1873b) sent Lorenzoni a telegram informing him that the Italian government had awarded to him 50,000 liras for the transit expedition.

Almost all the correspondence of 1874 (51 letters of Tacchini and 32 of Lorenzoni) concerns the organisation of the transit party. In January 1874, a frenetic activity started at the Padova Observatory workshop to collect instruments from other observatories, to improve and modify them, in order to make them ready for the mission. Lorenzoni (1874) sent Tacchini a note signed by Giuseppe Cavignato, mechanic of the Padova Observatory workshop, with the description of the works to be done and their cost, after a verbal agreement with Tacchini (Table 1).

Thanks to his competence in astronomical instruments, Lorenzoni was the scientific supervisor for new mountings, supports, for checking chronometers, chronographs, and for ordering new eyepieces and micrometers from Italian and foreign workshops.

Five telescopes were prepared and improved for the mission (see Fig. 3 in Pigatto & Zanini 2001) – a Starke equatorial refractor of the Observatory of Padova (117-mm aperture, 1.65-m focal length), a Steinheil refractor of the Observatory of Bologna (162-mm aperture, 2.60-m focal length), a Fraunhofer refractor of the Observatory of Turin, (117-mm aperture, 1.95-m focal length), a Starke altazimuth of the Observatory of Padova (117-mm aperture, 1.95-m focal length) and a 95-mm Dollond refractor of the Nautical College of Palermo. Other instruments, such as a Repsold universal instrument, three spectroscopes, chronometers, chronographs, thermometers, barometers, micrometers, other accessories and four pavilions to shelter the main instruments were prepared for the party. Two methods of observing the transit had to be used: the ordinary way, with telescopes equipped with heliometric micrometer or by projection, and with telescopes on which a spectro-

Figure 8. The Catania Observatory Merz refractor (340-mm aperture) on its equatorial mounting made by Giuseppe Cavignato at the Padova Observatory workshop (Padova Astronomical Observatory Historical Archives).

scope was mounted. Only the Italian astronomers planned to use this new device so fundamental for modern astrophysics. As a matter of fact, Tacchini (1874a) wrote to Lorenzoni:

> "Meanwhile, neither the Russians, nor the Germans, nor the English will use the spectroscope; this is a shame, bearing

in mind that these governments planned a lot of luxury expeditions. It seems to me that they could try to use it without changing their general program. Lockyer wrote me that he is disconcerted by Airy's refusal of this instrument which, I think, never has done anyone any harm."

Table 1. Works for the transit party and cost in Italian liras.

Radical modification and repair of the equatorial refractor of the Bologna Observatory, graduation of the circles, construction of a mechanism in order to adapt the instrument to whatever latitude from 0° to 50°; all has to be done so that the instrument can be improved at its best taking into account its present state	700
Very hard walnut 2.70-m high support for the previous instrument	300
Mechanism to adapt the Padova equatorial refractor to whatever latitude from 0° to 50°	200
Very hard walnut support of convenient height for the Padova equatorial refractor	200
Construction of a mounting completely like that of the Padova equatorial refractor for the Turin Fraunhofer refractor	2000

In July our friends started to organize the trip to Calcutta, in whose neighbourhood they planned to observe the transit. On 16 October 1876, the party left Venice on board of the *Sumatra*, a steamer of the "Peninsular & Oriental Steam Navigation Company".

4. Constructing Equatorial Mountings

Tacchini was very satisfied because of the instruments' perfect working order at the Venus transit in India; for this reason he thought that the Padova workshop was able to make large mountings for telescopes. In 1876, he was successful in convincing the Authorities to have new observatories built, one in Catania and one on Mount Etna. "I hope [Tacchini wrote to Lorenzoni] that this affair will be able to show that in Italy we have tools, that is mechanics, able to make large mountings without asking eternally abroad" (Tacchini 1876a). On 20 October, Tacchini (1876b) wrote to Lorenzoni about this new project:

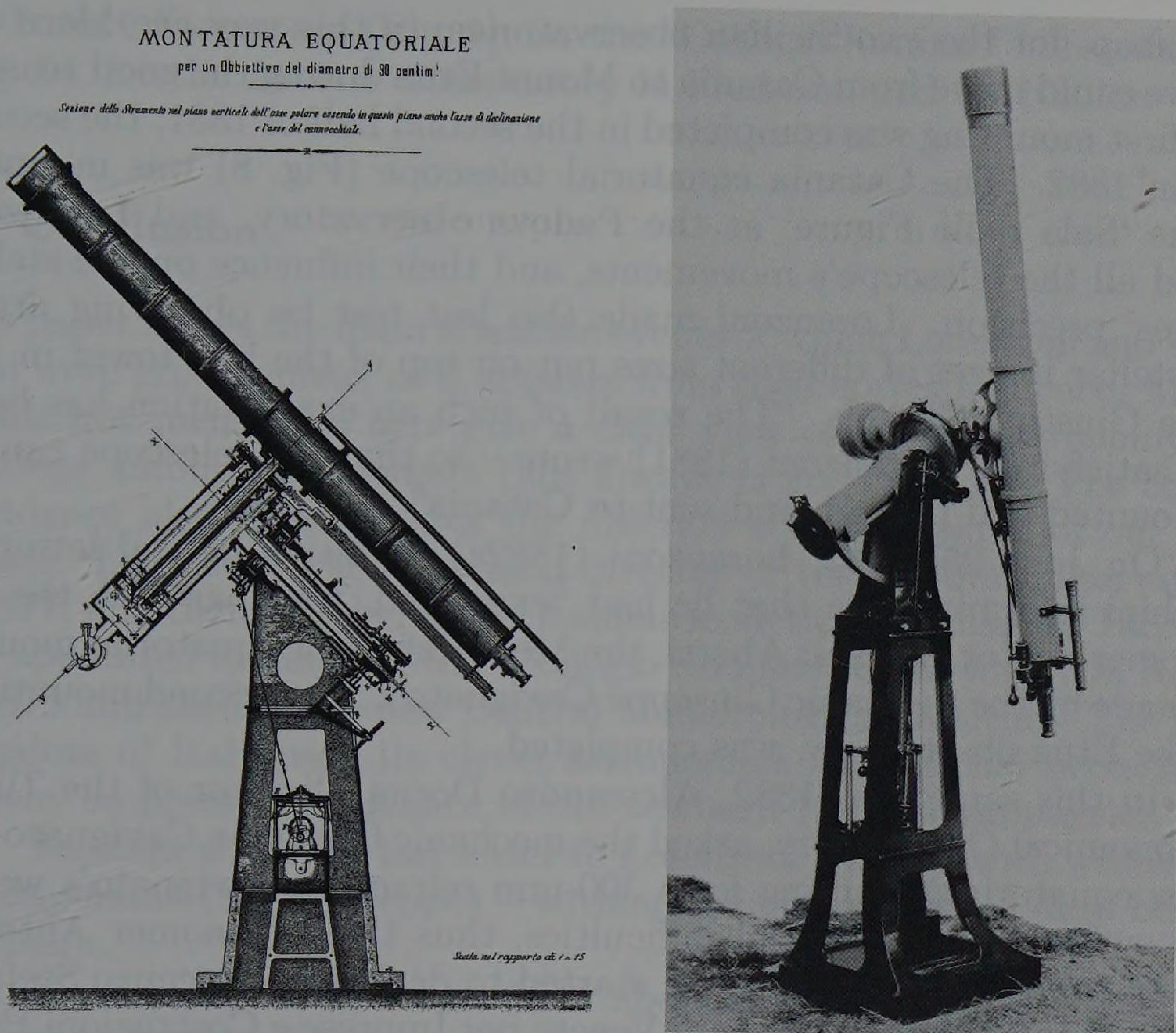


Figure 9. *Left:* Equatorial mounting for the 300-mm refractor of Turin Observatory: vertical section along the polar axis. *Right:* Equatorial mounting for the small Merz refractor of the *Collegio Romano* Observatory. Padova Observatory Archives.

> "I'm almost sure that the work will be done: I will have a great pleasure if your mechanics should be in charge of it, under your precious direction. You always encouraged me in this project, and now that it is achieving a serious aspect, I will be also more happy."

Many letters in the period 1876–1882 concern ideas, schemes, projects and costs for the two equatorial mountings. Some delay was due to the bureaucracy and to the difficulties because of political instability – change in government and ministers – in the new Reign.

Finally, Tacchini got a 340-mm objective lens, two tubes and the eyepiece lenses from Merz in Munich, and two equatorial mountings made by Giuseppe Cavignato, mechanic at the Padova Observatory

workshop, for the two Sicilian observatories; in this way the Merz objective could move from Catania to Mount Etna during the good season. The first mounting was completed in the second half of 1881, the second one in 1882. The Catania equatorial telescope (Fig. 8) was mounted in the 'Sala delle Figure' at the Padova observatory, and Lorenzoni tested all the telescope's movements, and their influence on the stellar images' precision. Lorenzoni made this last test by observing artificial stellar images of different sizes put on top of the bell tower in the Santa Giustina Church. "The result of such an examination has been very satisfying – Lorenzoni (1881) wrote – so that the telescope can be dismounted and packed, and sent to Catania".

On June 25, 1882, Lorenzoni (1882a) wrote an official letter to Tacchini informing him that he had "examined, together with the astronomer doctor Antonio Abetti, the Merz Refractor equatorial mounting made by the mechanic Giuseppe Cavignato". The second mounting, for the Etna observatory, was completed.

In this same year 1882, Alessandro Dorna, director of the Turin Astronomical Observatory, asked the mechanic Giuseppe Cavignato for a new equatorial mounting for a 300-mm refractor. Cavignato's workshop suffered from financial difficulties, thus the astronomer Antonio Abetti, supported by Lorenzoni, started to deal with Vincenzo Stefano Breda, president of the "Società Veneta per Imprese e Costruzioni Pubbliche", which made iron bridges, railways and aqueducts throughout Italy. The factory was located in close proximity to the Padova Observatory, and it would be able to help the small workshop with large constructions.

In November 1882, Lorenzoni (1882b) wrote to Tacchini that an agreement was signed among the Società Veneta, the Astronomical Observatory of Padova and the mechanic Giuseppe Cavignato. A new workshop was instituted of which Cavignato became workman in-chief. The workshop should be directed and administrated by the Società Veneta, the Observatory should only be scientific consultant. Shortly after, the Società Veneta sent the mechanic Cavignato with the astronomer Abetti to visit the Observatories of Vienna and Strasbourg in order to study their equatorial mountings, before starting new constructions.

The ambitious project of our two friends to make Italian industry able to construct telescope mountings for Italian astronomy, appeared to be achieved. However, many difficulties arose during the following years, due to envy and misunderstandings among Italian astronomers. Nevertheless, equatorial mountings were made by the Società Veneta for

the Turin Observatory (Fig. 9), for the "Collegio Romano" Observatory (Fig. 9), for the Arcetri Observatory in Florence, and for Naples.

5. Conclusion

This paper shows the main scientific events of which Lorenzoni and Tacchini were protagonists, as it appears from their correspondence. Many details not mentioned here give a clear view of Italian astronomy, of relations among astronomers (not always in good terms). The correspondence also demonstrates the different scientific paths of our two friends. Lorenzoni was appointed director of the Padova Observatory in 1877, and then member of the Italian Geodetic Commission; Tacchini was appointed director of the 'Collegio Romano' Observatory in Rome in 1879 and then of the new Central Meteorological Institute. The new Kingdom of Italy used its clever astronomers for national necessities, thereby stopping the advance of the newborn Italian astrophysics.

Tacchini wrote his last letter to Lorenzoni – a card with wishes for the day-name (St. Giuseppe) – without signature – seven days before his death.

A comment should be added about correspondence in general: history is known through official documents and reports, which are important because they ratify the events. Private letters throw light on many details which are very useful in order to know the 'truth' behind these events. The complete Lorenzoni-Tacchini correspondence will soon be published in Italian.

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ASTRONOMICAL HERITAGES: Astronomical Archives and Historic Transits of Venus
Journal of Astronomical Data, Vol. 10, 7, 2004
Christiaan Sterken, Hilmar W. Duerbeck, eds.

Old Georgian Astronomical Manuscripts

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Abstract

A general overview of Georgian astronomical manuscripts is given, and the contents of a few, dating from the 12^{th} to the 19^{th} centuries, are given. A partial translation and commentary of manuscript A883, entitled *Cosmos*, and dating from the 18^{th} century, is presented.

1. Introduction

A set of Georgian astronomical manuscripts is one of the most impressive testimonies of the evolution of the astronomical world view in Georgia, an evidence of development of scientific approach, a unique bearer of astronomical information, that has come down to us through Georgia's centuries-old history. Those hard centuries had brought up thousands of causes and reasons that could erase or consign to oblivion the unique scientific material. This might have happened to many old Georgian manuscripts. Nevertheless, museums, research institutes, libraries in Georgia, France, Russia, Greece and other European countries, and libraries and archives in Oriental countries house hundreds of old Georgian astronomical and astrological manuscripts, written in the old Georgian alphabet *Asomtavruli* (used in the 5^{th}–10^{th} centuries), and *Nuskhuri* (11^{th}–17^{th} centuries) as well as *Mkhedruli* (used since the 18^{th} century up to our days). Usually, the term *Khutsuri*, according to the comments frequently occurring for Georgian manuscripts, implies two Georgian alphabets – *Asomtavruli* and *Nuskhuri* (Machavariani 1984).

2. Astronomical Manuscripts

The astronomical manuscripts contain descriptions of celestial phenomena, the Sun, the Moon and planets, calendar systems, observation and calculation methods and other kinds of information. Many manuscripts give also descriptions of the climate and seasons, of certain geographical points, and mention names of astronomers and philosophers. A part of this complex of manuscripts is clearly of astrological nature, devoted to prophesizing human fortunes according to positions of the celestial bodies and celestial phenomena. This layer of historico-scientific information has been little studied and actually remains unknown to the western world. It is worth mentioning here Chagunava's (1990) *Vakhtang Bagrationi's Activities in Natural Sciences*, in which the author analysed several old Georgian manuscripts. Vakhtang VI Bagrationi (1675–1737) was a Georgian king, military leader and scientist.

Keeping close scientific and cultural contacts with countries of the western and oriental worlds, Georgia with her original old culture and scientific tradition absorbed elements of oriental cultures and cultural achievements of Western Europe. In this way a unique alloy of the original Georgian, Eastern and Western cultures was formed, and is reflected in the Georgian manuscripts, these historico-astronomical "mirrors".

Old Georgian astronomical manuscripts bear purely Georgian, as well as Persian, Greek and other names of places, persons and terms all written in Georgian; all non-Georgian names or terms being transliterated into Georgian alphabet characters. On the other hand, old Georgian astronomical manuscripts comprise purely Georgian scientific material. Reading their pages one can easily feel the beauty of the language, and the traditional world view of the Georgian author or translator. For many years, Georgian astronomical manuscripts used to be a subject of study only for philologists and linguists, both Georgian and foreign, their scientific aspect and significance remaining somewhat neglected. Now that nations and cultures are mixing, vigorously exchanging information, time has come to change that practice: by allowing the philologists to continue admiring the beauty of the language, it is our task to reveal the astronomical aspects of old Georgian manuscripts to present-day historians and astronomers. We find it essential to create a Georgian-English dictionary of historico-astronomical terms and names with their transcriptions, a project that would require great efforts. Another useful contribution would be the publication of English or French translations of some of the most important Geor-

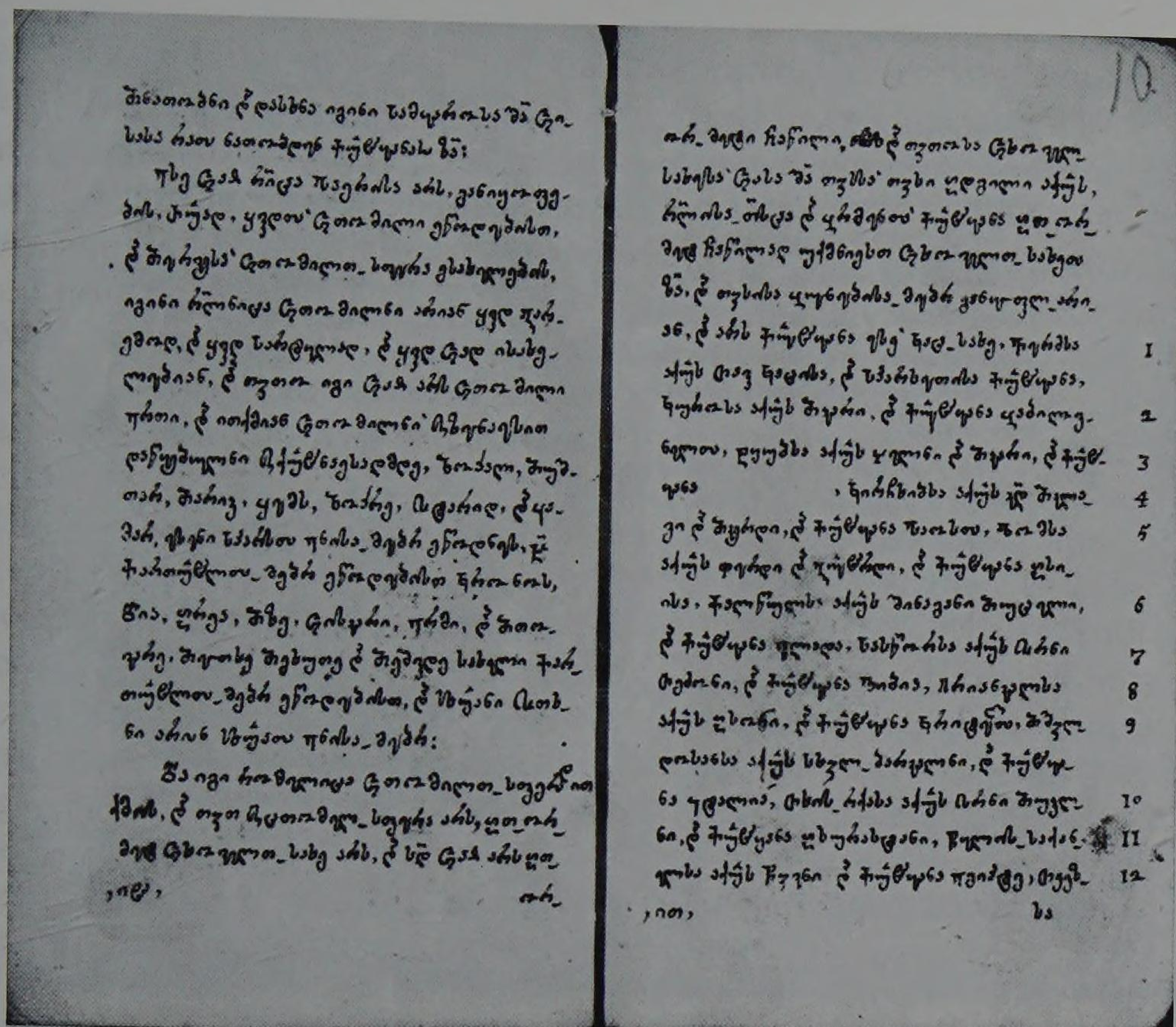

Figure 1. Astronomical manuscript A883, pages 18 and 19.

gian astronomical manuscripts with explanatory notes, comments and glossaries.

It is important to determine the total number of astronomical manuscripts written by Georgian authors, the number of those translated from other languages and the number of mixed manuscripts. This is a multilateral, time-consuming task, since many of the manuscripts were copied and re-copied many times. We hope that this task will be tackled in the future.

We will now consider several old Georgian astronomical manuscripts. The descriptions will contain our approaches and views and will, therefore, vary in volume – some will be brief, others more extensive. Old Georgian astronomical manuscripts are kept in the Research Institute of Manuscripts of the Georgian Academy of Sciences (Simonia 2001). The first catalogue of Georgian astronomical manuscripts was prepared by Kevanishvili (1951); the original is now kept at the Astronomy department of Tbilisi State University.

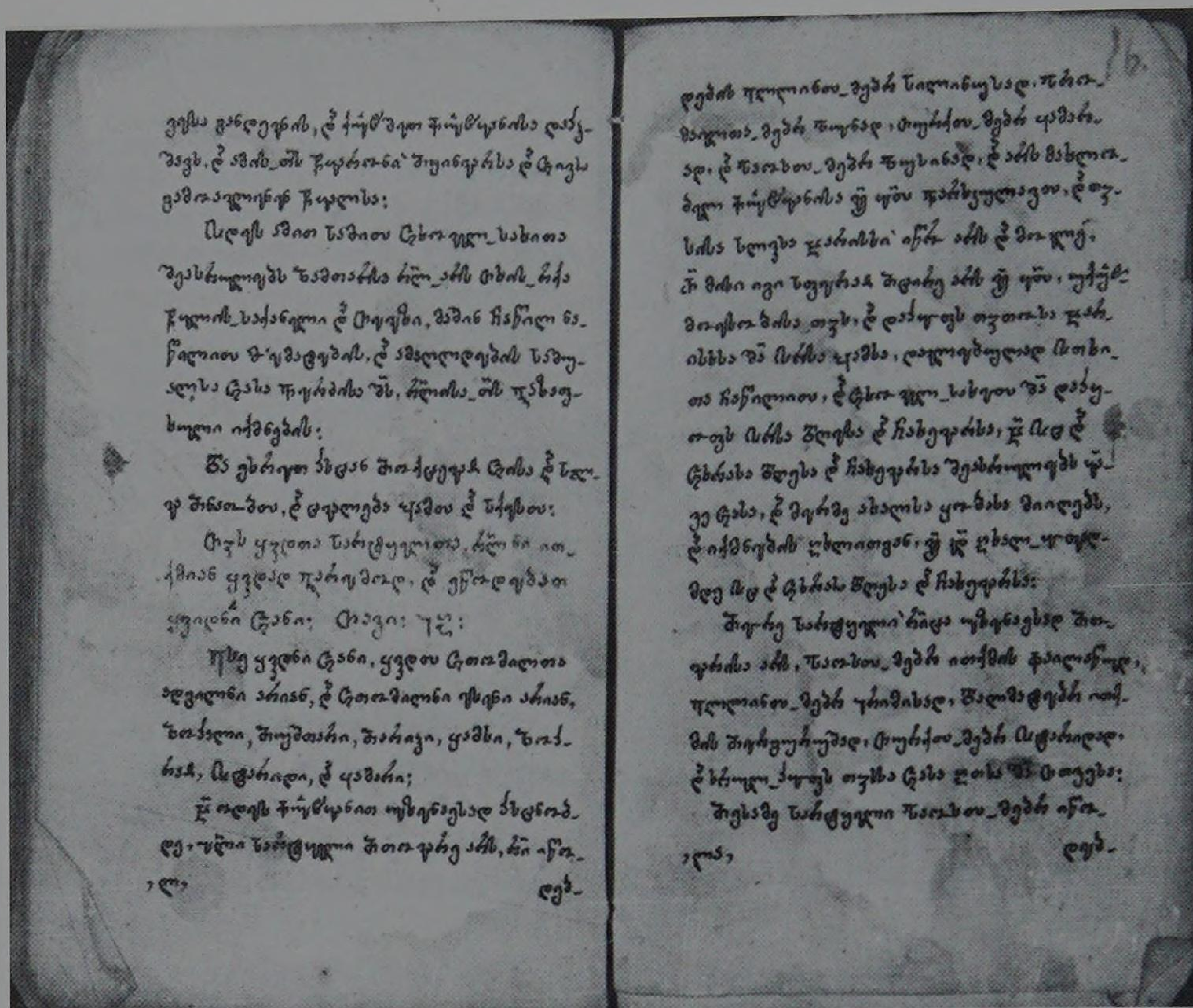

Figure 2. Astronomical Manuscript A883, pages 30 and 31.

Let us now dwell on the description of some manuscripts mentioned in Dr. Kevanishvili's catalogue. Number A24 is a *Khutsuri* manuscript of the 12th century AD, and signed by Efrem Mtsire, a Georgian philologist, philosopher and translator, who lived around the turn of the 11th to the 12th century. Its page 58 features 12 zodiacal constellations. The manuscript contains two books written by Ioanne Damaskeli (Ioannes Damaskenos) under the title *Legends.* Number A442 is a 75-page *Khutsuri* manuscript from the 15th century, containing a calendar from the 1st day of September to the 31st day of August. Number A684 is a *Khutsuri* manuscript of the 11th century. The manuscript comprises several chapters, one bearing the title *About the World.* The *Khutsuri* manuscript A718 of the 14th century gives descriptions of lunar days.

The *Mkhedruli* manuscript A889 written in the late 18th or early 19th century gives descriptions of the passage of the Moon through the constellations, defining the zodiac, identifying constellations by

the stars, giving the entry of the Sun into the constellations, and the appearance and disappearance of the Moon. Another *Mkhedruli* manuscript, H503, dating from 1808, gives descriptions of the Moon and stars, as well as ephemerides. The *Mkhedruli* manuscript S5237 from the 19^{th} century describes the science of the Sun and the Moon.

This is only a small part of information contained in Dr. Kevanishvili's catalogue. Its descriptions are somewhat irregular, and occasionally rather disordered. We tried to keep the author's style, both in the terms and complete sentences. It is hardly possible to judge the accuracy of the catalogued description of the above listed manuscripts without actually reading them. Therefore, the catalogue can be regarded only as the first approximation of a large unified catalogue of Georgian astronomical manuscripts that has to be created by collective efforts. What makes Dr. Kevanishvili's catalogue particularly valuable is that it is the first regular code of information about Georgian astronomical manuscripts. Among the manuscripts listed above, there are original works of Georgian authors as well as translations. Unfortunately, they have not been studied for their astronomical significance; some of them are in quite poor condition and need to be copied and restored for future generations of researchers.

3. Astronomical Manuscript A883

Let us discuss in detail the *Mkhedruli* manuscript A883 of the 18^{th} century, catalogued under the title *Cosmos*. It consists of 42 pages and is divided into chapters. The first chapter is named *On the Heavens: in what amount the heavens exist, what they are made of, and by whose order.* On the first page the text begins with

> "The Creator built this World with His wisdow and power. And He made the World visible... To create the World He used four matters – the fire, the wind, the water and the earth. These are the foundation of everything and each other's opposites. From these matters He created meadows and beasts. And no other matter was heavier than the earth, more fluid than the water; no other matter was more mobile than the air (wind), no other matter was brighter than the fire."

We will try here to render a translation, as close as possible to the original text, although it is a rather difficult task. The anonymous

writer describes, in the first place, the very first steps of creation of the Universe. There are some exchangeable terms used in the text, for instance *the wind* is replaced by the word *air* as a synonym. Another point worth noticing is that the author refers to the opposition of different forms of matter. Is that a reference to previous sources or does the unknown author realize the differences in the physical nature of these forms of matter? This way of interpreting things was quite common in the 18^{th} century, though.

On the second page of the manuscript we read

> "And the Great Prophet Moses said: He created for the basis the Heaven and the world. The Heaven presents two matters – the fire and the air; and the world is made of two matters – the earth and the water. And while He created those four matters, the art of His wisdom showed itself in putting, the heaviest earth below, and placing the water on the earth, and setting the air which was lighter than water, above the water, and placing the fire which was lighter than air, above the air, with moisture observable in the air itself."

The second chapter of the manuscript begins on page 5 and has the title *About a second Heaven and about its motion.* The author continued with the description of the process of creation of the world referring to the bible, in a way simplifying and abridging the biblical text.

Chapter 7 *about the airy Heaven in which the Luminaries are* starts on page 17. The anonymous author writes:

> "As the Holy Bible says, God made lights (Luminaries) and set them in the Heaven to give light upon the Earth. The airy Heaven is divided into 8 parts, 7 of which are called planets and the eighth is the sphere of planets. Those which are planets are called seven circumferences, seven belts, seven Heavens. Each Heaven is one planet. And the planets are listed from the highest to the lowest: Zokhal, Mushtar, Marikh, Shems, Zokhre, Otarid and Kamaz. These names are Persian. For the Georgians they are Kronos, Dia, Area, Mze, Tsiskari, Ermi and Mtovare. The 4^{th}, 5^{th} and 7^{th} names are Georgian; the others are in a different language. And that which is called the sphere of planets and which is a planet-sphere itself, has a face of 12 beasts. The Heaven has 12 parts. Each beast has its place in the Heaven."

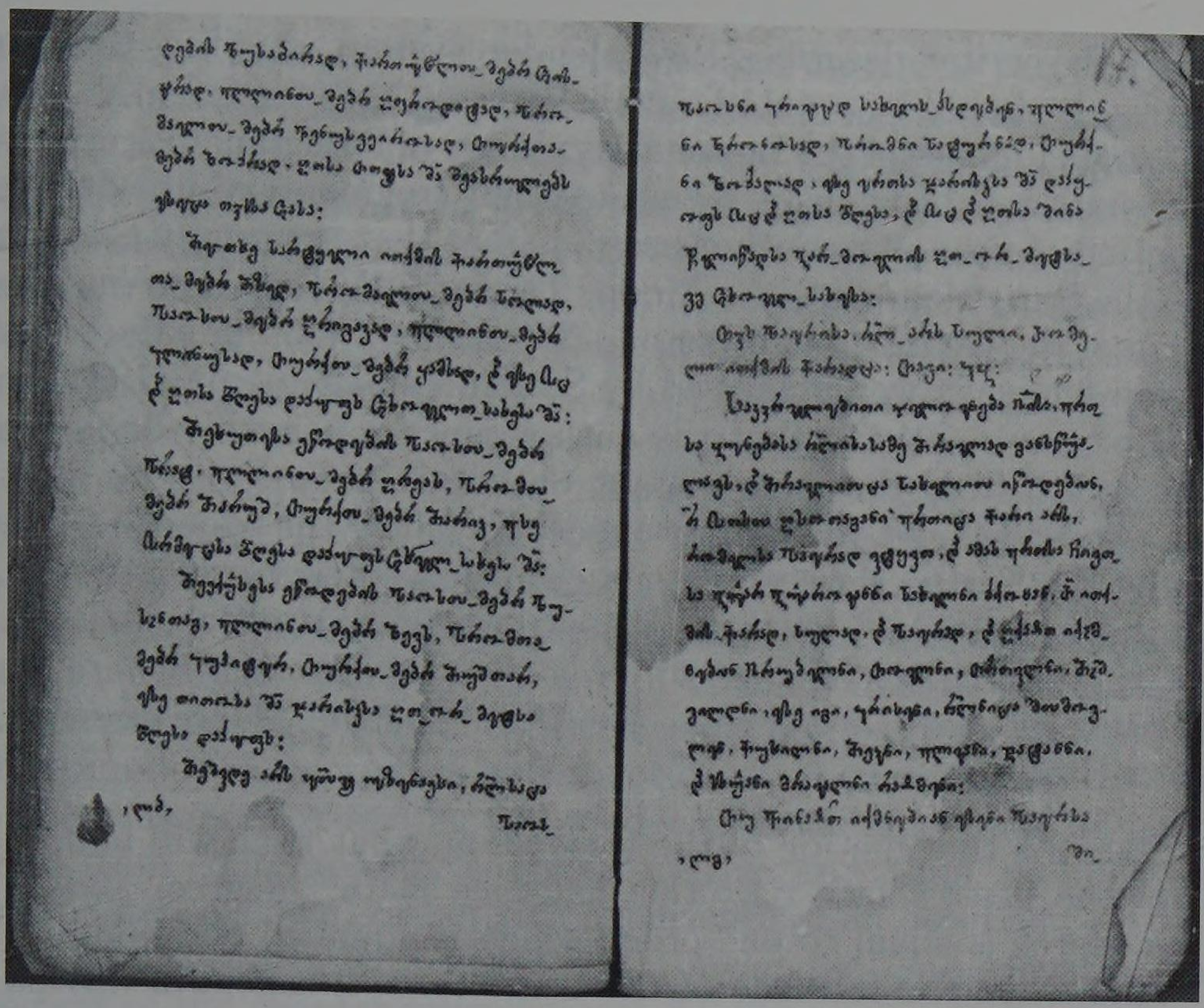

Figure 3. Astronomical manuscript A883, pages 32 and 33.

Then, the author continues to name the zodiacal constellations giving each of them a number and a country. The list of countries includes both Eastern and Western ones. For instance, "Sagittarius has thick thighs and the country is Italy 9, Capricornus has two knees and the country is Asurastan 10, Aquarius has juice and the country is Egypt 11, Pisces has two legs and the country is India 12." The Gemini constellation had no country and the name followed by a free space and a comma. Fig. 1 shows pages 18–19 of the manuscript with the names of planets and constellations with the respective countries. The pages in this manuscript are lettered. The writer continues:

> "and there are 12 beasts in the Heaven and 12 months in a year, and each beast has 30 degrees which are 30 days of a month. The Heaven has 360 degrees which are 360 days of a year, and 5 more additional days appear as small fractions of another chronology."

Further, the writer describes the calendar system, dividing time into centuries. It should be pointed out that the author uses oriental, Greek and Georgian names of the Luminaries. Many of foreign names acquired a Georgian *tinge*, obviously, owing to their fragmentary use during a long period of time. The author uses 3 names that are purely Georgian: Mze – the Sun, Mtovare – the Moon, Tsiskari – Venus. The questions of origin of the Georgian names and adaptation of foreign names in the Georgian language were analysed by Simonia and Simonia (1994).

It is worth noticing that the author put the heavenly bodies in a certain order, from the most distant Saturn to the nearest to us, the Moon. And what did the author expect to follow the Moon? – It was certainly the Earth. Here we have a clear geocentric world attitude of the author. In the 18$^{\text{th}}$ century? Was it late Georgian geocentrism?...

Chapter 8 begins on page 20: *How does the Celestial Sphere Move ad Rotate and How Do the Sun, the Moon and the Stars Move?* The author writes:

> "what is that motion of the Heaven; at what time will half of the beast's face rise; this half-face is 15$^{\text{th}}$ degree, and 5 degree is equal to one order which is equal to one hour. And when the full face of the beast rises, 2 orders of day will pass."

It should be mentioned here that the author used the term *tsvai*, which can be translated into English as share, order, quarter.

Then the writer gives an example of finding the Sun in the constellation of Aries (spring). He describes the movement of the zodiacal constellations in the sky, for instance, how Aries would, within a certain period of time set behind the horizon in the West, as he put it, into the inner hemisphere, On page 22, we find a description of repetition of rising and setting of constellations, the Sun, the Moon and stars.

Page 22 opens with Chapter 9: *What Examples Evidence that the Sun and Other Luminaries Move from the East.* The text runs:

> "You should also know that the Heaven rotates from the East to the West while the Sun and the Moon and stars move from the West to the East, and their beams will fall southwards."

Furthermore, the author describes in general terms the phenomenon of culmination of celestial bodies. With some faults though, he touches upon the annual motion of the Sun and other bodies, giving further examples, clarifying the diurnal and the annual motion of celestial bodies,

examples that refer to the life of people and animals. The writer continues: *You should also know, that when the Moon is new, it will move into the Sun and will appear in the West. Day after day, facing the East, it will move and when it becomes 12 days old, it will become faint and appear in the East.* Apparently, the author is trying to describe the lunar phases. Later in the text, the writer refers to the rotation of the Earth around its axis. Then again he goes back to the Sun's annual movement through the zodiacal constellations, giving some of their names.

Analyzing the text of the manuscript, one may come to a dual conclusion, namely that the material was set out in a somewhat irregular and inconsistent way, though, on the other hand, the author was clearly aware of the essence of the phenomena he was describing. Here arises the question whether the author of the manuscript obtained this knowledge from his personal experience and observations, or whether he only compiled data, results and theories of other scientists. He seems to have possessed a regular knowledge of astronomy that he had acquired from contemporary sources. At the same time, he might have accumulated his own, rather rich experience of an observer.

Page 25 starts with chapter 10, *About the four parts of a year.* The text of the chapter tells:

> "There is another motion and transition of the luminaries which descend from the North to the South and ascend from the South to the North and give rise to four sections of a year – spring and summer, autumn and winter. There are four sides: East, and West, North and South. And wise men divided the world into 12 parts.
>
> When the Sun goes into Aries and when Libra appears opposite Aries in the West, day and night will become equal and spring will set in. Following this, every day will grow by one part. And the Sun will rise facing the North. And the Sun will pass there faces of beasts – Aries, Taurus, Gemini and there will be spring. When the spring time sets in, seedlings and plants will come to life, people will look beautiful, flowers will bloom, and birds will be born. And after the Sun has moved to the North, though the faces of three beasts, the spring time will be over, and the Sun will go into Cancer and summer time will begin."

We might have re-shaped stylistically the translation of the narration of the anonymous author, but we consider the manuscript as a

historico-scientific document and give a more or less verbatim translation, retaining its roughness and inconsistency. The author's ideas are quite clear. Despite some lack of perfection, they reveal the author's understanding of the reasons for the annual changes in the Sun's altitude above the horizon depending on its ecliptical motion.

Chapter 11 tells *About Seven Belts Which are Spoken of as Seven Worlds, and they Are Called Seven Heavens.* We read:

> "These seven Heavens are places for seven planets. These seven planets are Zokhali, Mushtari, Marikhi, Shamsi, Zokhrai, Otaridi, Kamari... The first belt is Mtovare, which is called Silinus by the Hellenes, Luna by the Romans, Kamar by the Turks, Lusin by the Haoses and it is not far from the world of stars, and the degree of its motion is narrow and short. Its sphere is small and it spends two hours in every degree, diminishing by a fourth part, and spends two-and-a-half days in every beast's face, and completes the whole Heaven within 29 and a half days, then gets a new birth and everything begins all over again."

We see that the author gives different names to the Moon, from Mtovare in Georgian to Lusin in the language of the Haoses (Armenians). He also describes the lunar motion, and defines precisely enough its synodic period. The author continues:

> "The second belt that is above the Moon is called Failatsu by the Haos people, Irmi by the Hellenes, Mergurush by the Dalmati people, Otarid by the Turks. This luminary completes its orbit in 10 months. The third belt is Lusabir for the Haoses, Tsiskari for the Georgians, Aphroditi for the Hellenes, Venusveiro for the Romans and Zokhra for the Turks; and this luminary completes its orbit in 10 months. The fourth belt is called Mze by the Georgians, Sola by the Romans, Origav by the Haoses, Ilinus by the Hellenes, Shams by the Turks. This luminary spends 30 days in the face of each beast. The fifth belt is called Khrat by the Haoes, Area by the Hellenes, Marush by the Romans, Marikh by the Turks. This luminary stays in the face of a beast for 40 days. The sixth is called Lusintag by the Haoses, Zevs by the Hellenes, Jupiter by the Romans, Mushtar by the Turks. This luminary stays in each degree for 12 days. The seventh is the uppermost; the Haoses refer

to it as Irivak, the Hellenes as Cronos, the Romans as Saturn and the Turks as Zokhal. This luminary stays in each degree for 30 days, and it will pass through the faces of all 12 beasts in 30 years."

Figures 2 and 3 show pages 30, 31 and 32, 33, respectively. This is actually the complete 11^{th} chapter of the manuscript.

An analysis of the abovementioned text section reveals the author's good knowledge of astronomical achievements in different foreign countries. He mentioned Georgians, Hellenes, Romans, Haoses, Dalmats, Turks, which means that he has studied astronomical sources in different languages, such as Greek, Turkish and others. This is evidence of his good general education, in particular, his high level training in astronomy. However, there are some flaws in the definition of periods of rotation of some celestial bodies. Were they errors in the sources or his own mistakes in some measurements? – It is hardly possible to answer this question at present.

The author gives a wrong period of revolution of Mercury. The period of rotation of Venus was given with a smaller error (we mean its sidereal period). However, the author was correct in giving the period of *rotation* of the Sun through the zodiacal constellations. And again, quite a big mistake was made in the period of rotation of Mars.

Assuming, that the term "degree" implied 1.01 angular degrees, the period of rotation of Jupiter will be equal to 4277.2 terrestrial days. This value is close enough to that of the true sideric period of the planet. The author was quite precise, too, in giving the period of rotation of Saturn. Our assumption that each degree is equal to 1.01 is correct, which is confirmed by the author of the manuscript when he states for Saturn "30 days in one degree". Calculation based on the assumption of 1 degree being actually 1.01, results in the number 10693, i.e. 29.3 years. The slight difference between the value 29.3 derived from the author's assumption and the value 30 cited by him elsewhere might have been a result of some errors in the calculations, or using data from two different sources, for instance, an older manuscript and his own calculations.

After the 11^{th} chapter, the contents of the manuscript alters a little, its narration changing from a schematic, step-by-step style to a more generalized one. The author proceeds considering the cyclic character of natural phenomena, though not their agronomical aspects, but climatic ones. The narration itself sounds more like a lecture on nature. It is worth pointing out that in this part of the manuscript the writer, referring to the celestial bodies, no longer used the Georgian

term *mnatobi* meaning *luminary*, that was used in chapters 1 to 11, but another Georgian word, *varskvlavi*, meaning *star*. It appears that the author refers to other literary sources while writing this part of the manuscript. Chapters 12 to 22 are devoted to the descriptions of changes in the weather throughout a year, to the wind, mist and other phenomena. The writer describes the rainbow, with quite a correct general perception of its nature. He tries to describe the appearance of a meteor and some other events. On the whole, this part of the manuscript is of somewhat ambiguous character. On the one hand, some events are treated correctly from a physical point of view; on the other, a number of phenomena are misinterpreted. For instance, in the description of the thunderstorm, he does not even suspect that the light and the sound move at different velocities.

The text of the manuscript contains neither mathematical descriptions of natural phenomena, nor graphs and drawings. It is rather of a descriptive, narrative character. Neither the first nor the last pages of the manuscript reveal the name of the author or the writer. Considering the contents and style of the manuscript, it appears to be a brief manual or text book on elementary cosmography. Anyone possessing an intermediate level or respective knowledge could study the material and apply it in practice. The contents of the manuscript seems to have been designed for scholars of intermediate grades, both of clerical and secular schools. The style of the narrative, the author's level of interpretation of natural events, the list of the countries cited and the fact that the writer used the *Mkhedruli* alphabet, as well as characters of the old *Asomtavruli* alphabet, all strongly indicate a 18^{th} century origin of this manuscript. In that age, without technical devices for making copies, rewriting of historical and historico-scientific materials was the only possible way to preserve them. They were copied again and again, year after year, century after century. This is the way how many old Georgian historical and scientific documents have reached us. And here credit goes to scientists and philosophers as well as to numerous clergymen who had been copying for us old Georgian manuscripts and documents. They seemed to take care of the history of science and history of religion, realizing the importance of handing down the inheritance of knowledge, skills, ideas to future generations. If the above considerations are correct, this copy from the 18^{th} century may be based on an original Georgian manuscript of the $11-16^{th}$ centuries, and this fact may give us the clue to the puzzle of the late Georgian geocentrism.

As concerns the dating of the plausible original manuscript, two points should be mentioned: (a) the *Mkhedruli* alphabet used in the

document doubtlessly indicates an 18th century origin of its composition; and (b) the copyist of this elementary cosmography never used the ancient Georgian names of the luminaries: Jimagi (Mercury), Mtiebi (Venus), Tarkhoni (Mars), Obi (Jupiter), Morige (Saturn). These ancient Georgian names had been used both in western and eastern parts of Georgia up to the third century AD (Simonia 2001). Items (a) and (b) may serve as additional indicators in the process of exact dating of this *elementary cosmography*. The scientific contents and the style of narration suggest that the original belonged to the mid-period of the process of formation of the Georgian astronomical world view. A correct dating of the original text is a complicated task calling for further investigation.

The analysis of the "Elementary Cosmography" is certainly not completed. The document ought to be compared with similar foreign sources. In short, it will take quite a lot of efforts, but the first step has been made, and we will appreciate any ideas, questions and counter-arguments.

Acknowledgements

The author would like to extend his gratitude to Dr. Wayne Orchiston and Dr. Suzanne Débarbat for their support enabling him to contribute the report to the IAU General Assembly. The author would also like to thank Dr. Raul Chagunava for fruitful discussions.

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ASTRONOMICAL HERITAGES: Astronomical Archives and Historic Transits of Venus
Journal of Astronomical Data, Vol. 10, 7, 2004
Christiaan Sterken, Hilmar W. Duerbeck, eds.

Storing Astronomical Information on the Romanian Territory

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ABSTRACT

Romanian astronomy has a more than 2000-year old tradition, which is, however, little known abroad. The first known archive of astronomical information is the Dacian sanctuary at Sarmizegetusa Regia, erected in the first century AD, having similarities with that of Stonehenge. After a gap of more than 1000 years, more sources of astronomical information become available, mainly records of astronomical events. Monasteries were the safest storage places of these genuine archives. We present a classification of the ways of storing astronomical information, along with characteristic examples.

1. Reasons for this Survey

Although the civilization on the Romanian territories is very old – there are testimonies since the Neolithic – a series of factors impeded a good conservation of knowledge accumulated throughout the centuries. Numerous natural calamities (earthquakes, floods, fires etc.) led to the disappearance or definitive destruction of numerous documents attesting the existence of an important culture in this part of Europe. In addition, as a consequence of invasions, wars, or internal struggles, important historical documents have been destroyed, often on purpose.

Improper conservation sometimes had similar effects: improvised restorations, such as those of the sanctuary at Sarmizegetusa, where, in order to ensure its resistance, pillars almost two millennia old were cemented; amateur restorations of some frescos led to the destruction of the original stratum; old texts were copied without protection. Storage

of documents in unsuitable rooms, full of humidity and dust, rodents, moths, etc. often adds to the decay. In addition, ideological blindness in the second half of the 20^{th} century has lead to additional destruction or misinterpretation of such documents.

This review serves to elucidate the situation which the study of the history of astronomy in Romania faces. Today we are confronted with: (1) the lack of systematic studies and archives on the history of science (implicitly, of astronomy); (2) a lack of interest in the conservation of scientific testimonies; (3) a wrong outlook on their role for the progress of modern society.

We have to start with a systematic study of what has survived, and we hope that more documents will come to light, and will give evidence that this part of Europe made a conspicuous contribution to world astronomy and culture. We hope that this review is a first step for an ample research of monitoring, classification and study of the testimonies of an old astronomical culture on the Romanian territory.

2. Romanian Territory

In order to make our efforts of the analysis of astronomical archives in Romania better understood, we shall characterize shortly its territory (Fig. 1). It is situated in the Carpathian-Danubian-Pontic area, has three main historical provinces, in which traces of civilizations dating back from the Neolithic have been preserved.

The best-known is probably Transylvania. For several centuries it belonged to the Austro-Hungarian Empire. The Carpathian mountain chain is the geographical protection against numerous invasions from the east, and led to a faster evolution of scientific knowledge, of education, and to a longer and better conservation of scientific archives. Nevertheless, many observatories, instruments and documents were destroyed, and the misinterpretation, even the falsification of some writings or their provenance were not, unfortunately, isolated cases.

The province to the North-East of Romania, Moldavia, is known as a territory of great cultural sensitivity, which, at least in the last centuries, left firm marks in the national and European culture. Closer to the culture of western Europe, and farther from the influence of the Ottoman Empire (which each time was achieved through great sacrifices), the very hospitable Moldavia has probably been the province that attracted most foreign travelers, such as Boscovich, Fernando di Marsigli, or Theodor von Oppolzer.

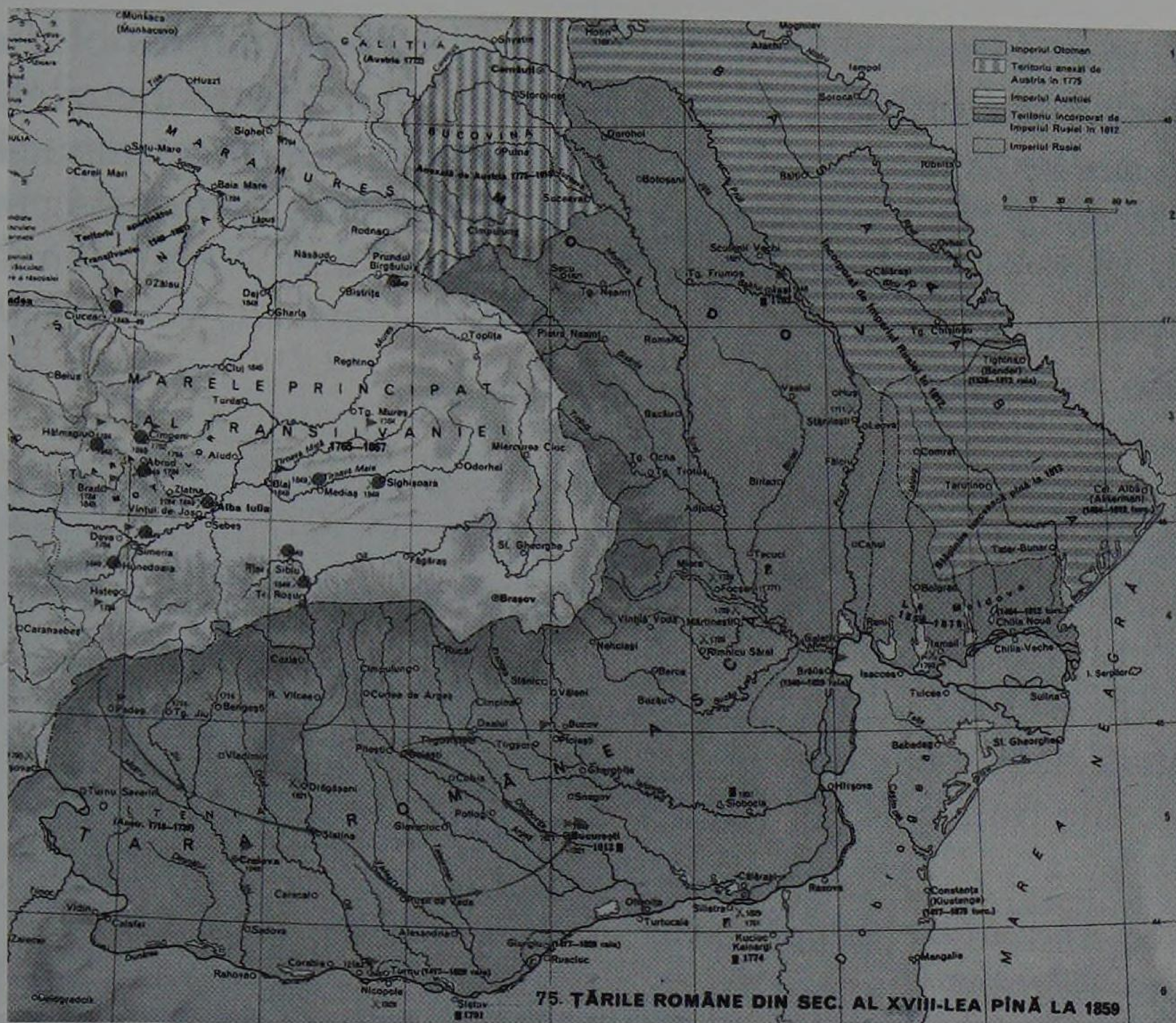

Figure 1. The Romanian Territory.

The third important province, Wallachia, is the region which includes the present-day capital of the country, Bucharest. Maybe it was the region most exposed to invasions, to oriental influence (Turkish – Balkan). However, the need to resist, defending itself, sometimes developed more inventiveness, intelligence, science. This might be a reason why lately Romanian culture and science has concentrated here.

3. Traditional Modes of Information Storage

For a complete analysis of the archives, which can be studied today on Romanian territories, we give a classification of these archives, and then give a short review of these types.

The oldest archives, some of which are still in good condition, are those of stone or of wood. Due to a completely original artistic sense and to some techniques, which have not been entirely deciphered, the monasteries, especially those in Northern Moldavia, are unique in the world, and the frescos of some of them are present-day testimonies of the astronomical knowledge of the times when they were built. The

richest archives remain the written ones, preserved, in most of the cases, also in the monasteries. The oral tradition should not be overlooked, because it preserves names of constellations and other testimonies of the scientific level of the respective regions or of the epoch of its creation.

4. Stone and Wood

Neolithic necropoles. The earliest traces of culture on Romanian territories date back to the Neolithic. This epoch is characterized by an impressive number of necropoles: Cernica, Parta, Iclod, to name just a few. The cult of the Sun is obvious, from the orientation of the graves (towards the sunrise direction on the day of the burial) to the cult objects that have been preserved, on which cosmic elements are very numerous, the Sun holding the most important place.

Dacian sanctuaries. Much later, in the epoch of the Dacians and of the Roman Empire, the native population found protection and inspiration especially in the mountains. The Meridional Carpathians still preserve an impressive number of sanctuaries, which had a complex role: religious, defensive, of community gathering. The sanctuaries at Costesti, Piatra Rosie, Anines, Gradistea Muncelului are only some examples, they were built approximately two millennia ago.

Probably the last one is the best known, because it is near the Dacian capital, Sarmizegetusa Regia, and serves as the best illustration of the level of knowledge of that epoch. It dates from a period of flourishing culture and civilization, which was strongly influenced by the predominant Greek-Roman one.

The stable character of the Dacians within the geographic area defined by the Carpathians, the Danube, and the Black Sea offered to this people a proper horizon of knowledge. Their life in general, but especially the commercial and military activities, imposed a good astronomical knowledge.

The sanctuary at Sarmizegetusa Regia (or Dacica) is a genuine astronomical observatory of that time (Fig. 2). This fact must not surprise us; there are appreciations about the level of the Dacian culture, which go back to Herodot (5^{th} century BC). The Gothian historian Jordanes believed that in this region of the world there were persons "almost as erudite as the Greeks". In his work *De origine aetibus que Getarum*, he wrote that the Dacians knew the 12 zodiacal signs, the manner in which the Moon waxes and vanes, the names of 346 stars,

etc. Therefore it is explainable why the great circular sanctuary preserved at Sarmizegetusa illustrates perfectly the level of astronomical knowledge of our ancestors concerning the Universe, the time, the seasons, the geographic and astronomical orientation. The sanctuary has a calendar system which is still insufficiently studied, but the Andesite Sun is a jewel of universal culture, unfortunately badly preserved and very little known.

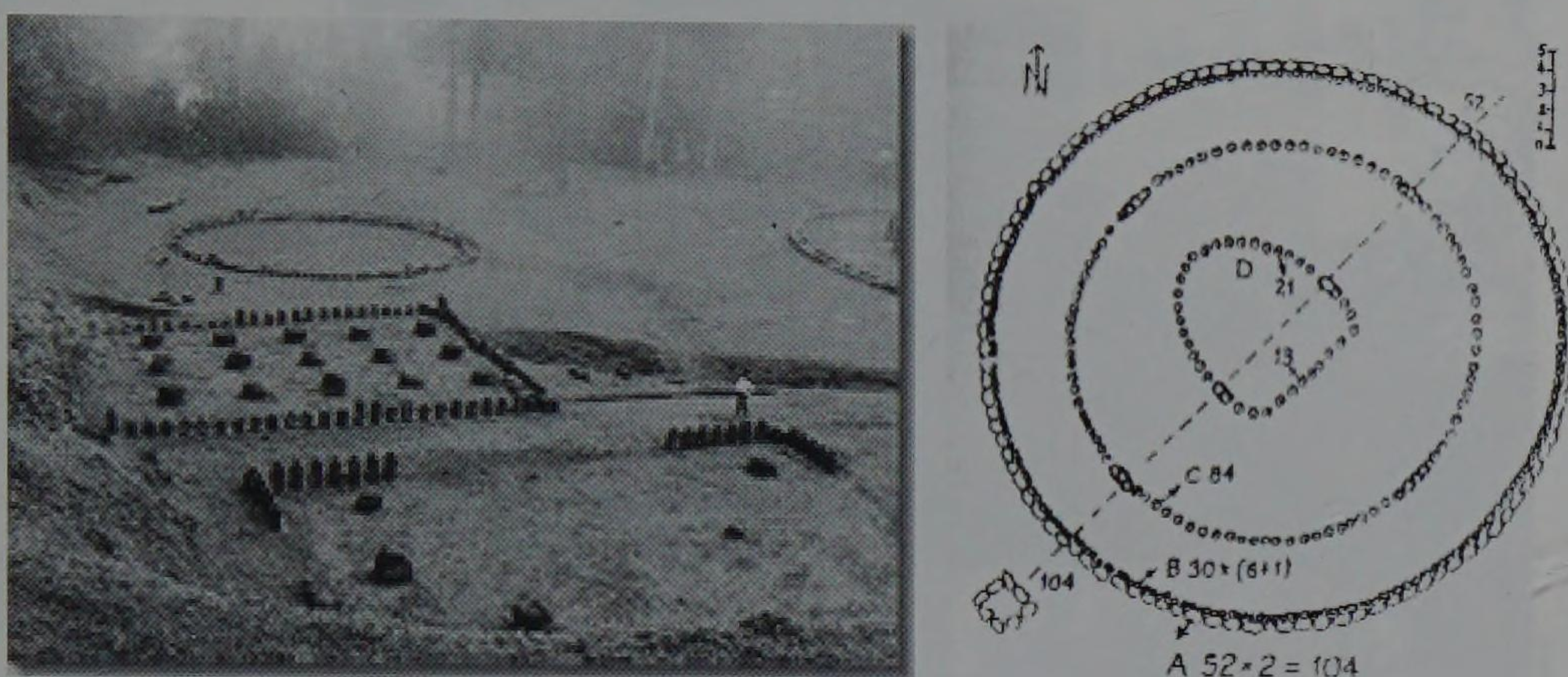

Figure 2. Sarmizegetusa Regia: view of the great sanctuary and its reconstitution.

Churches. We have mentioned the orientation of the tombs; this tradition is strongly rooted on the Romanian territories and the most eloquent proofs are the churches, which have an extremely rigorous orientation, not only to the East, but also to the sunrise direction on the day of the patron. Something like that could not have been solved without a precise knowledge of the daily motion of the Sun and without a well-established calendar. Actually, as all over the world, the time recording and especially the calendars were the reasons for the observation of the starry sky and the establishment of some rules, which were often original and very ingenious. The same tradition applies to the old village houses. Unfortunately it is rather an oral tradition, because on account of the materials used (mainly wood or adobe) hardly any houses which are two or three centuries old have survived.

Sundials. The best known testimonies of stone, spread all over the world, and thus also on the Romanian territories, are the sundials. Most of them are real works of art and proofs of an impressive technique for the respective epoch; we like to mention especially those placed on

the churches (Oradea, Cluj, Campulung). Most of them are a true demonstration of the knowledge of time measurement, not only from the point of view of the craft, but also from that of the establishment of periodicity in chronometry, of the knowledge about the lunar and planetary motions and about our own planet in general.

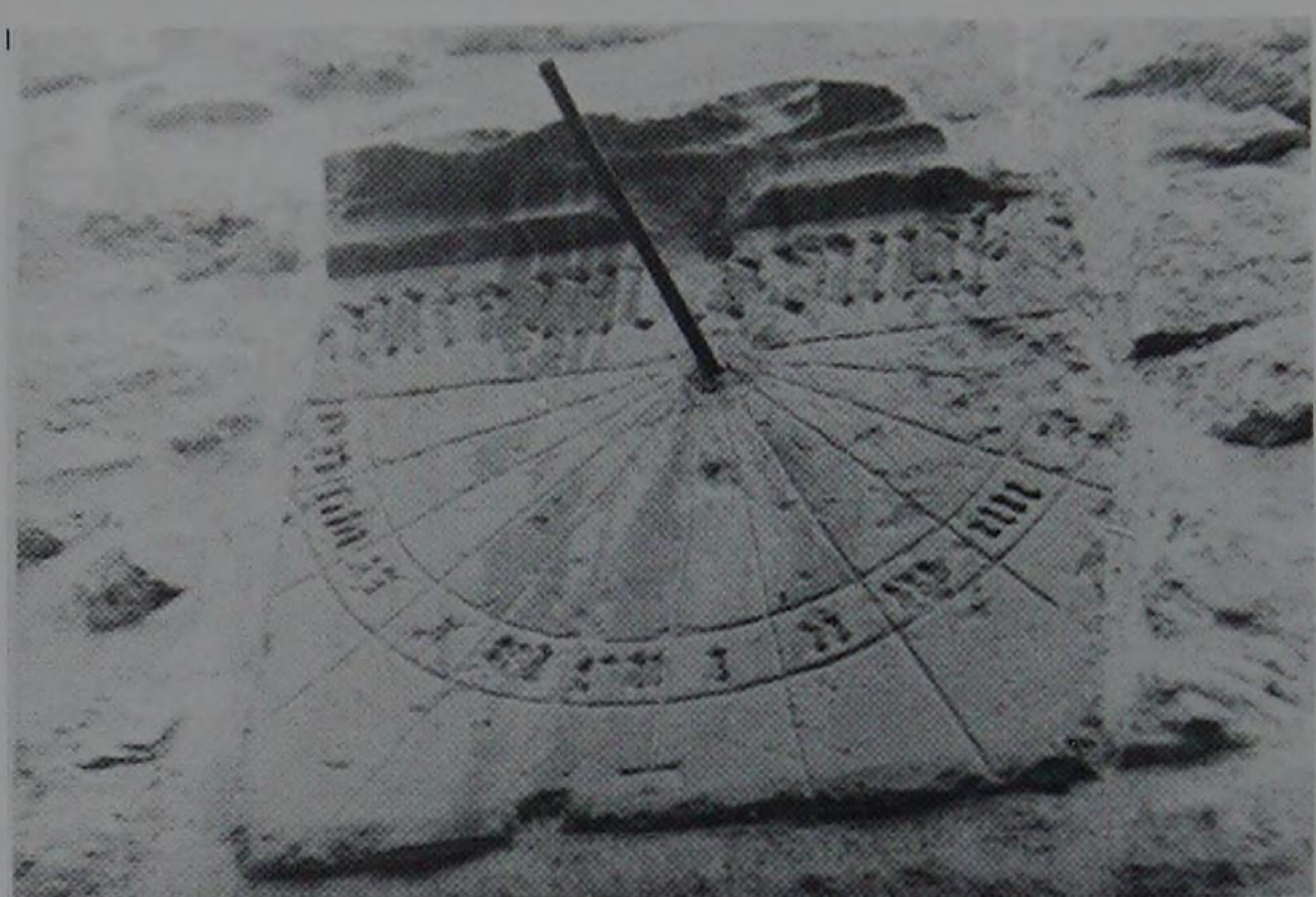

Figure 3. Sundial.

Observatories. If we speak of astronomy and of stone constructions, we should think in the first place of observatories, and have to specify the meaning of "observatory". There were observatories, in the true sense of the word, buildings especially arranged for the observation of the sky. Taking into account the situation of these territories, their number was small, and most were destroyed by natural calamities or invasions, but we know that the greatest part of them existed in Transylvania, protected by the Carpathian chain.

We begin with the first known astronomical observatory on Romanian territory, set up in Oradea. It was built in the 15th century, a century before Tycho's Uraniborg, which was built in 1576. Its founder was a scholar, theologian and scientist, the Transylvanian bishop Ioan Vitez (1408–1462). Tutor of Iancu de Hunedoara's[1] sons, he was concerned with literature, art, music and astronomy. He was also the observer of the Episcopal court, where he was a bishop between 1445

[1]Iancu de Hunedoara, commander of armies, was born into a family of Romanians, and appointed Prince of Transylvania in 1441. Chevalier of the anti-Ottoman fight, he scored great European victories against the Turks. He died of black death while in full glory, in 1456.

and 1465. Aware of the fact that the value of an observatory resides both in its astronomers and in the instruments with which it is endowed, he invited famous mathematicians and astronomers, like Georg Peuerbach (1423–1461) from Vienna, his collaborator, Regiomontanus, or Ioan Nihili from Prague, to work in the observatory.

Figure 4. Batthyaneum Observatory.

The exceptional material advantages offered by the bishop allowed Peuerbach to endow the observatory with quality instruments and with a rich library of books and maps of astronomy. In the famous Almagest by Ptolemy, to be found today at the national library in Vienna, on the map at the end of the book, several personal notes on stellar positions are kept.

Among the observatory's instruments was a gnomon geometricus, used to determine the height of the stars and a solar clock with instructions for use. Vitez asked Peuerbach to make the necessary calculations of some important astronomical phenomena, especially in order to foresee future eclipses. In 1456, the first results were published in *Tabulae Waradienses*, calculated for the meridian of Oradea. It was the first work of this type in Eastern Europe, was published several times, and practically spread throughout the entire continent. Vitez also asked

Peuerbach to write a theory of the planets, based on the principles of heliocentrism. Let us not forget that the famous theory was published only several decades later by Copernicus (1543). Ioan Vitez's interest in astronomy continued at the University in Bratislava, founded by him at the request of King Matei Corvin[2]. Evidence for these special preoccupations of Vitez, which were continued there, are the planetary positions requested by him from the famous mathematician and astronomer Regiomontanus[3]. Unfortunately, all that has been left of the Observatory in Oradea are several instruments kept in the city's museum.

Other observatories were founded in the 18th century, by Nicolae Ianosi in Cluj, and in Alba Iulia at the Batthyaneum.

5. Pictography

If an image has always been a testimony of the epoch when it was made, as far as archive storing is concerned, it has the disadvantage of deterioration with time, especially in the very early periods when techniques did not allow the fixing of the colors on various materials.

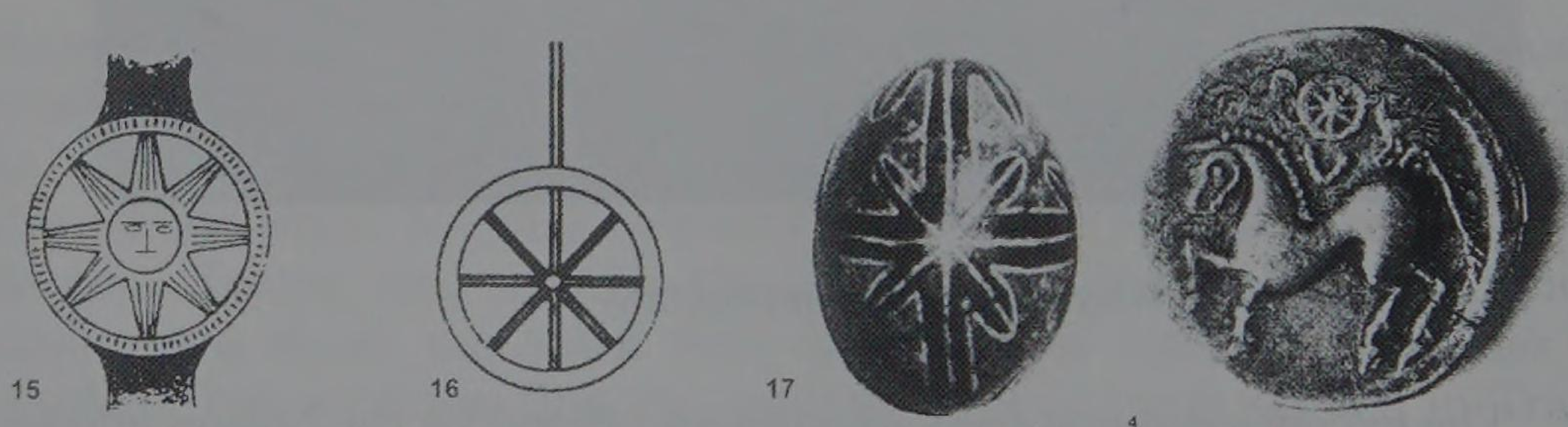

Figure 5. Ceramics, painted egg and coin.

The variety of the materials on which various cosmic symbols were drawn is impressive. Naturally, each one deserves a special study, but as with the other fields of astronomical information storage, we shall only mention them here. They are drawings on stone, ceramics, leather,

[2]Matei Corvin (1440–1490), Iancu de Hunedoara's son, King of Hungary (1458–1490).

[3]Johannes Regiomontanus (1436–1476), German mathematician and scholar, one of the first astronomers who considered that comets were bodies in motion.

pergament, wax, jewels; even the painted eggs for Easter often have cosmic symbols, especially the Sun and the Moon, but also comets and constellations. Metal with drawings of cosmic inspiration, too, is a proof of the astronomical knowledge, especially as, due to its durability, it is better preserved, such as the Dacian shields, coins, medals or iron nails.

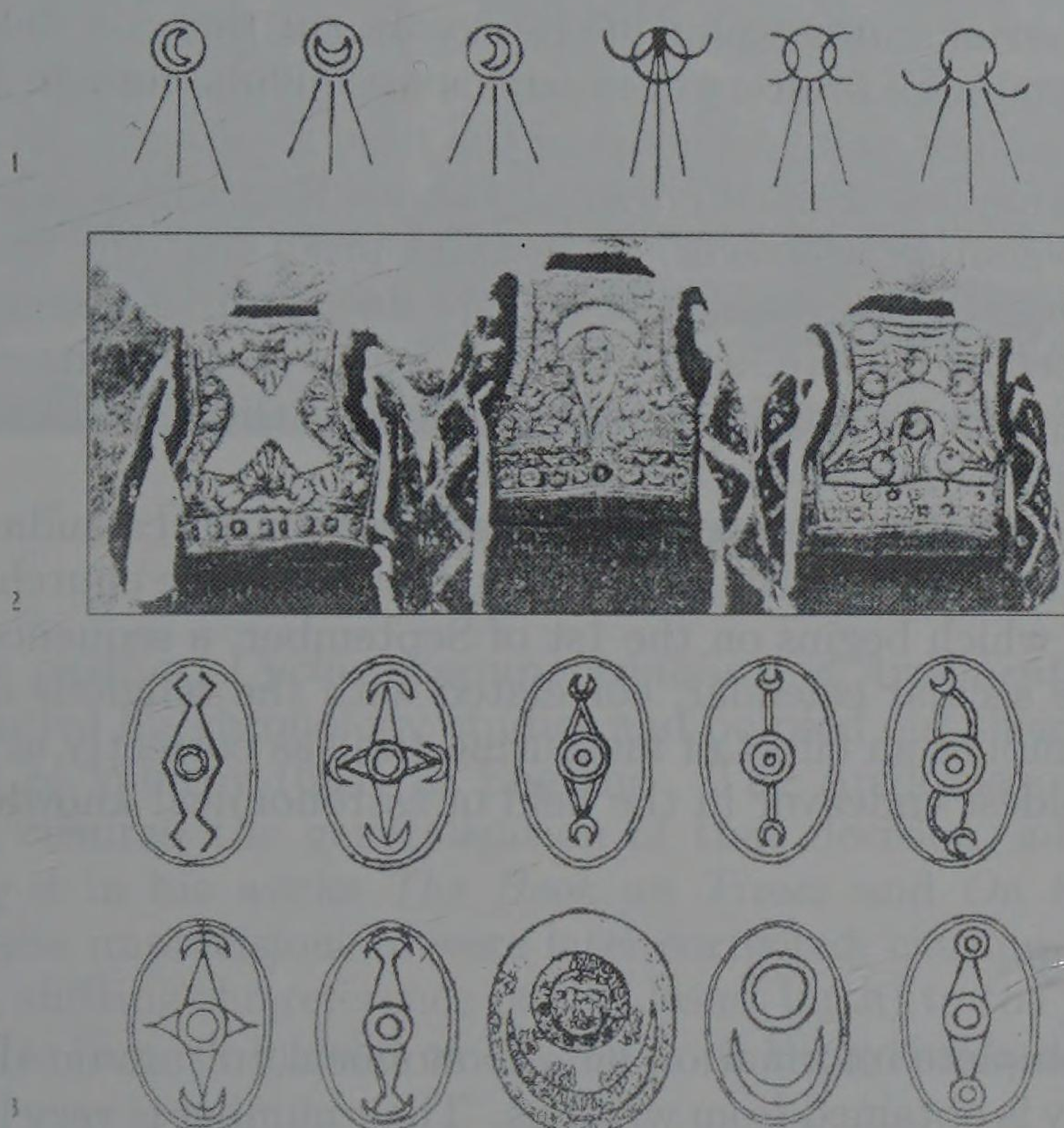

Figure 6. Folk clothes.

With the Romanians, icons hold a special place, especially those on glass. Besides the fact that they represent true works of art, which are slowly entering the world patrimony, no special study on the topics of the iconography represented has been made yet, especially as many of the religious topics which they contain refer either to the star of Bethlehem or to other events with a cosmic connotation.

An attempt of systematization of the cosmic representations has already been initiated in a domain less studied on world level. It concerns the coats of arms and the seals. The heraldic language uses man, animals, arms, but also celestial bodies: the Sun, the Moon, the terres-

trial globe are symbols frequently represented on the coats of arms of the Romanian rulers, starting with the 14th century.

Romanian civilization has an exceptional iconographical record, a rarity at world level: the exterior frescos on the Moldavian monasteries. The harsh climate of the region, the Eastern winds, and especially the great variations of temperature or humidity, have made the preservation of the colors very difficult throughout the centuries. Nevertheless, some are still preserved and the blue of the sky on the fresco of the Voronet Monastery remains a mystery even to this day. These frescos were compositions of modest painters, most of the time local ones. As far as we know, they were not trained either at famous Romanian colleges or at Western universities. However, as an extra proof that the monasteries held the supremacy of Romanian culture for centuries, these painters had an important culture, as we can see from the portraits of ancient philosophers, well known for their cosmological theories, like Aristotle or Plato, on the walls of the monasteries.

Evidence of their astronomical knowledge are the calendars painted inside the churches. Traditionally, in the first room the church calendar is displayed, which begins on the 1st of September, a sequence of icons following the secular calendar, correlated with the religious one. Naturally, this implies an effort of measuring time as correctly as possible, maybe the oldest endeavor in the field of astronomical knowledge.

6. Writings

The most complete information on astronomical culture on the Romanian territory is obtained from writings. Their number is very large, and they have been studied by many specialists, historians or astronomers, although so far we cannot speak of a systematic study of all the documents existing in libraries and maybe even in private collections.

7. Original Works

As concerns original works, the oldest ones we know are the writings of Dionysius Exiguus (470–540), the famous author of the chronology since Jesus Christ's birth. Born in present Dobrogea, or Scytia Minor, according to the name it had in the Roman Empire, Dionysius the Small has his place in historiography due to his establishment of a new era, the Christian Era. His chronological studies remain immortal due to the titles of his writings and his astronomical calculations:

Figure 7. Fresco with portraits of ancient philosophers.

De ratione paschae, Cyclus decemnovennalis and Argumenta paschalia. Beda defended his chronology studies and pointed out their value after the synod of Whitby (664) in England. The Anglo-Saxon Beda the Venerable ensured the generalization of that decision, adopting and explaining it in his works *The Book on Times* and *On the Logic of Times.* Some imprecisions of were later corrected, causing a difference of 4 years, shifting the reference point (Jesus' birth) to the year 758 *ab urbe condita* (a.u.c.) instead of 754 a.u.c. as Dionysius had calculated.

Eticus the Historian, the author of a *Cosmography*, lived at the beginning of the first millennium. In the 8th century, the Presbyterian Ieronim asserted that he had translated a *Cosmography*, a description of the world made up by the philosopher Eticus, named by him "philosopher, sophist (wise man), cosmographer, sophogram", from Greek into Latin, in the form of a summary. We have limited ourselves to the oldest writings which are kept at the Vatican.

8. Copies or Translations

There are also several copies or translations of great value catalogued in the Romanian territories, all kept in monasteries. These were the only places less exposed to repeated attacks, offering not only a place

for peace of mind but also for culture. The monk Silvan from Putna Monastery in Northern Moldavia, the monk Antim from Cozia Monastery and Anatolie from Ramnic Bishopy (the last two being situated in Oltenia, a South-Western province of Romania) translated important works for the Romanian culture in general and for the astronomical knowledge in particular.

9. Chronicles

The greatest part of the testimonies about the preoccupation with celestial phenomena is recorded in chronicles. Besides important political or social events, the chronicler recorded other events as well, from those concerning the daily life, to the very rare ones considered to deserve to be known to posterity.

The total solar eclipse of August 12, 1654 (chronicle of Sibiu). On the 12th of August [1654] there was a big sun eclipse, as never happened before. It was pitch-dark, so that three stars could be seen by the sun, while birds in the air were forced to find shelter, unable to fly. The eclipse lasted from 9 to 12 o'clock, and it caused many misfortunes and troubles, mainly to our poor Transylvania, in years, as we shall show further on.

Comet 1556 Fabricius (chronicle of Brasov). 1556...A comet was seen on the third of March, at around 9 o'clock in the evening, in the eleventh degree of the Balance, in a shade of black, dim and flowing into deep purple, with a very quick motion. On the fifth day of March, it was by the Balance, leaving towards the Equinox circle by 60 parts. It advanced during all these four days by 75 parts from sunrise to sunset and by 30 parts from south to north, and then it remained above the horizon. Since the end of March, so much heat came so that the constitution of that month was like the one of the month of June. As astrologers said, it meant misunderstandings concerning the laws, and plague especially in regions such as Germany, Pannonia, Asia, Greece, and the Nordic countries.

Comet 1680 Kirch (chronicle of Jassy). In the year 7188, A.D. 1680, in the month of December, on the 10th day, there appeared in the sky a tailed star, which the Romans called "cometa", that means "broom". It was so long that it covered half the sky by its length, rooting in a star, down the Hungarian parts, between south and sunset. Then, day

by day, it went on rising up towards north, shortening itself, as the way of the sky, with the stars turning towards sunset. As such it went on for seven weeks and four days, until the 1st of February.

10. Notes on Books

Annular solar eclipse of July 14/25, 1748. Let it be known that since the sun perished, on Thursday, the 14^{th} of July, seven o'clock in the morning, and was in the dark for three hours, little was left aside. When ten o'clock rang, light became master again.

Total lunar eclipse of 14/26 January 1823. In the year 1823, on January 14th, on Sunday night, on a clear sky, at three o'clock in the morning, by full moon, it got dark, as it became like a fresh liver. After that bloody paint got off, only half of it remained, and it got whole again only in one hour, while we were all wondering what this omen would mean.

Comet 1858 VI Donati. In the year 1858, a sign in the sky turned up, worse mentioning, i.e. since the 13th of September in the evening, after sunset, a tailed star was seen, at about Feldioara. It followed the sun and went on at about ten o'clock in the night, and went up again before the sun in the morning, two hours before. The tail was upwards to the night's pole, setting and rising until the beginning of October. Since then, it moved to the sunset, and, day by day, its tail grew, and it grew so much that on the 7-8-9 October it reached 10 stanjens, and was 3–4 traits wide at its end. It was so brilliant just like the full moon. Then it followed its way towards the sunset, until 14–15 October, when nobody could see it anymore.

11. Inscriptions

Some interesting notes were found scratched on the walls. One of them, on the wall of a church in the Romanian town Brasov, was noted by the French astronomer François Arago:

Comet of 1569. 1569. Comète dont l'apparition a été constatée par une inscription sur les murs de l'église de Cronstadt, en Transylvanie.[4]

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[4]F. Arago, *Astronomie populaire*, t. II, Gide, Paris, Weigel, Leipzig, 1858.

12. Letters, Diaries and Personal Documents

An important contribution to the Romanian astronomical archives could be found on private documents, as letters, diaries. We give, as example, only one letter:

Comet 1853 III Klinkerfues (from a letter by A.S. Degan, addressed to Victor Anestin). In the year 1850 or 1852, I was a child of seven and was living with my parents at Ocnele Mari (Valcea), when I saw a comet in the sky, in the month of May. Back then the people called it "a star with a tail". It was seen to the west, after sunset and the more the night was falling, the better it was seen. The tail of the star was upwards: about three parts of the tail made up a whole, while the part to the top was split in several strips or tongues, of an amazing, bluish brightness, which vibrated. In the beginning, when the star was seen, the tail was smaller, but it continued to grow, until, as the people used to say then, it had a length of 4–5 fathoms. The star with a tail used to set two or three hours after sunset, for how many days the star with a tail could be seen in the sky I cannot remember.

13. Oral History

The need to find out more about everything that surrounds us, the unforgettable impression left by the cosmic phenomena, the need for orientation, for chronology, all of this combined with the remarkable sensitivity of the population in this part of Europe made its folk tradition register a thesaurus of astronomical knowledge little studied so far. The legends or the names of stars and constellations are so beautiful that they are still used even today, even in the current language, to identify a celestial point of reference. Unfortunately, the beauty of the language used makes any translation lose its value. Nevertheless, we give in Table 1 several examples, which reflect the ingenuity of the popular author.

14. Astronomical Archives

The things presented above describe the old documents which can still give important information both for the identification of phenomena rarely seen on Earth and for the establishment of level of knowledge about the cosmos of the population on the Romanian territories. But

Table 1. Examples illustrating the beauty of the language.

Term	Translation
Polaris	Holy candle of the sky, pillar of the sky
Aldebaran	Piggish morning star, walker, bull's eye
Pleiades	The hen with its brood, the little hen
Cassiopeia	God's throne, monastery
Auriga	God's chariot
Cygnus	Great cross of midnight
Orion	The three Kings, the plough with harrows
Perseus	Devil's chariot, the hatchet
Milky Way	Grove of the sky, Trajan's path, way of slaves

there are more recent documents, which could make up a genuine scientific archive, which, unfortunately, had the same fate as the others.

There are observation notebooks still unread (the observation notebooks of the astronomers from the nineties and from the early twenties), while there are others which have been causally discovered in the libraries of other observatories of the world (observation notebooks of the Romanian astronomer C. Capitaneanu, which are kept in the library of Paris Observatory).

Scientific drawings (the solar activity observed at the beginning of the 20$^{\text{th}}$ century by Maria Teohari) have been accidentally discovered in a public observatory, and the conditions in which they are kept will soon make the ink go away forever.

Photographic plates or observation films have only now begun to be scanned and digitized, and we hope that their analysis will allow a minute research of the recorded images.

15. Conservation Sites

From the short review of the types of documents existing on the Romanian territories we can conclude that the places where they are can be relatively easily identified. Most of them are in places in nature (necropoles, sanctuaries, churches, peasant gates, etc.), monasteries (books, paintings, artworks), museums (books, paintings, artworks), personal libraries (books, paintings)and official libraries. Consequently, their classification, conservation and analysis are not impossible.

16. Conservation Conditions

A more complicated problem is their state of conservation. It could be qualified in the following ways:

Good. This is the state in which we appreciate that the photographic plates (at least those at the Astronomical Institute in Bucharest, where there have not been too high variations of humidity and temperature) have been preserved, and at present a systematic digital archive storing has begun within the Sky archive international working group.

Medium. However, in this state some photographic plates stored in rooms with normal humidity, but uncontrolled light, dust, temperature can be first included. A series of artworks restored within some financial limits has a similar state. In the conditions of some rather severe financial restrictions, the first budget cuts which are usually made are oriented towards what is "old" and "obsolete". That is why it is with great difficulty that the necessary funds can be found for most of the conservations and even more so for the establishment of a genuine astronomical museum, which Romania does not yet possess. There is already a hall of 200 square meters which has served until recently for meridian observations and where, through local efforts, objects of historical value are being gathered: however, a systematic presentation of these objects requires adequate financing.

Bad. Unfortunately, as we have already mentioned, many valuable objects are in a state, which is at least bad. We have mentioned drawings inadequately kept, old books photocopied unprofessionally. Even worse, the restoration of some sanctuaries, which already belong to world culture, such as that at Sarmizegetusa, was made also unprofessionally, even with utter negligence.

Destructive. Last but not least, we have to mention the commerce with patrimonial artwork (ancient vestiges, icons on glass, etc.) and the indifference or contempt to real cultural values.

17. Conclusions

This short review of the main archive sources proves that the Romanian territory holds an enormous scientific and cultural thesaurus, which is worth being studied, conserved and capitalized, both for the Romanians

and for world culture. The arguments in favour of these needs are the following:

History. From the historical point of view, the archives play a twofold role: by reminding us that one cosmic phenomenon or another took place at the time of a certain ruler or of a certain battle, they allow us to establish the respective data on the basis of the astronomical ephemerides. The reverse of the medal is also valid: knowing that a cosmic phenomenon was associated with a known historical event, we can identify the phenomenon. Only that in both cases one should analyze carefully, because often, by desire to give greater glamour to a certain ruler or to emphasize how dramatic a foreign intervention on our territories was, we discover with amazement the distortion of the date of the astronomical event intended to make it match the terrestrial event.

Understanding the Romanian Mediaeval Mentality. The research of the astronomical archives leads us to the discovery of a forced connection between celestial phenomena (generally considered omens) and terrestrial events, also as far as the social calamities (wars, change of rulers, mutinies, death of prominent personalities, etc.) are concerned and in the case of the natural calamities (earthquakes, floods, weak harvest, grasshopper invasions, plague, drought, epizooties, etc.). A simple analysis of these correlations is enough for the portraying an epoch from the points of view of the people's mentality, of the way in which they reacted in their relation with nature and how they were prepared to do this.

Art. As we have already said, all the archives at our disposal hold not only valuable scientific information, but also a high artistic sense, a special originality, a high sensitivity that maintain the characteristics of this zone, but are nevertheless well integrated in the world culture.

Philology. In a similar context we must also situate the use of a rich old Romanian language and the language evolution under the influence of other cultures. As it has been observed lately, language sometimes experiences a spectacular evolution. Or, in a region so much devastated by the invasions of peoples coming from all the cardinal points, with different cultures and languages, it is natural that language should evolve. The important thing is that, probably due to the struggle for the preservation of the national identity and maybe also due to religion

(the Romanians consider themselves a people which was born Christian), here language preserved its vocabulary essentially, but did not stand still. All the chronicles and the documents studied have proven this, although the goal of our investigations has been a purely scientific one, related to the astronomical information.

Astronomy. To end, as astronomy has been the main goal of this investigation on the role and way in which the cultural patrimony on the Romanian territories can be capitalized, we should like to remarks that the richness of written records offers valuable information to astronomy; and some written records provide priorities for the Romanian astronomy, such as the first observation of comets 1569, 1819 II, 1839; the only European observation of the 1592 comet; the only naked-eye observation of the comet 1819 IV, and the first European observation of the head of the comet 1843 I.

Finally, the number of documents studied is still very small, and their study has not been done very profoundly to exhaust all the information they can offer. All this will bring out both the culture existing on this land and its contribution to world culture. At the same time we expect to find surprises concerning data about some astronomical events observed only once or about which we have not even heard. The most important thing is that this attempt to systematize the sources of astronomical archive storing on the Romanian territories should lead to the following step: the analysis of each part, for the benefit of Romanian culture and also of the universal one.

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ASTRONOMICAL HERITAGES: Astronomical Archives and Historic Transits of Venus
Journal of Astronomical Data, Vol. 10, 7, 2004
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The Archives of the Norman Lockyer Observatory

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Abstract

The archives of the Norman Lockyer Observatory are held in the library of the University of Exeter and comprise two distinct groups of documents. Firstly, correspondence and other papers of the astronomer Sir Joseph Norman Lockyer (1836–1920) and secondly, correspondence and working papers of the Norman Lockyer Observatory at Sidmouth, Devon; these are mainly for the period 1921 to 1961. A catalogue of the letters received by Lockyer from over 900 correspondents has been prepared and the listing of the other papers is in progress. In addition, the Observatory holds a collection of over 8000 photographic plates, of which over 6000 are of stellar spectra, especially of variable stars, some of which are from the 19th century.

1. Introduction

This description of the archives of the Norman Lockyer Observatory that are held in the library of the University of Exeter is based on the presentation given during the 24$^{\text{th}}$ General Assembly of the International Astronomical Union in Manchester, UK, at the meeting of Commission 41 on 2000 August 16. Additional information about subsequent changes in the their management and about other related material is also given.

Norman Lockyer was born in 1836 and became an amateur astronomer and science journalist during the 1860s while serving as a clerk in the War Office. In 1868 he devised a spectroscopic method

of observing prominences and this led to a change to an academic career at what is now the Imperial College in South Kensington, London, where he set up and directed the Solar Physics Observatory. He was the editor of *Nature* from its founding in 1869 until 1919 and he wrote 17 astronomical books. He was knighted in 1897 and he received many national and international honours. The biography of Lockyer by Meadows (1972) contains an extensive bibliography while a summary of his scientific work is given in Wilkins (1994).

One of his sons, W.J.S. Lockyer, became an astronomer and the assistant director of the Observatory. Sir Norman retired as professor of astronomical physics in 1901 and two years later he married a widow, Mary Brodhurst, who had inherited land at Sidmouth in Devon. They built a retirement home there in 1910 on the slopes of Salcombe Hill. Then, at the suggestion of Francis McClean, the son of the astronomer and philanthropist, Frank McClean, work started in 1912 on the building of the Hill Observatory on the ridge above the house. Activities there were interrupted by the First World War, and the appeal for funds was not as successful as Lockyer had hoped, so that his 30-inch reflector was never installed on the new site. Sir Norman died in August 1920 and the observatory was renamed the "Norman Lockyer Observatory". His son became director until his sudden death in 1936. The two main telescopes, known as the Kensington and McClean Telescopes from their origins, were twin refractors and were used mainly for stellar spectroscopy. This period is described in Wilkins (1998).

In 1948, after the Second World War, the University College of the South-West of England at Exeter, now the University of Exeter, provided additional funding and, in effect, took control of the NLO Corporation, which was a company with charitable status that owned the Observatory. Astronomical observing ceased, however, in 1961 and the site was then used for various geophysical observations. All activities ceased in the early 1980s, except for limited use by the local astronomical and amateur radio societies. The library and archives were transferred to University of Exeter. In 1986 the NLO site was sold to East Devon District Council and the furniture and auxiliary equipment were sold by auction.

The Council sold some land and out-buildings and it used the proceeds to refurbish the domes and the McClean Telescope and to build an extension to the Mond Building to provide a meeting room and a radio room for use by the local societies. The Observatory was re-opened in 1989 (see Ward 1990) just after I had retired from the Royal Greenwich Observatory and had moved to Sidmouth. The NLO

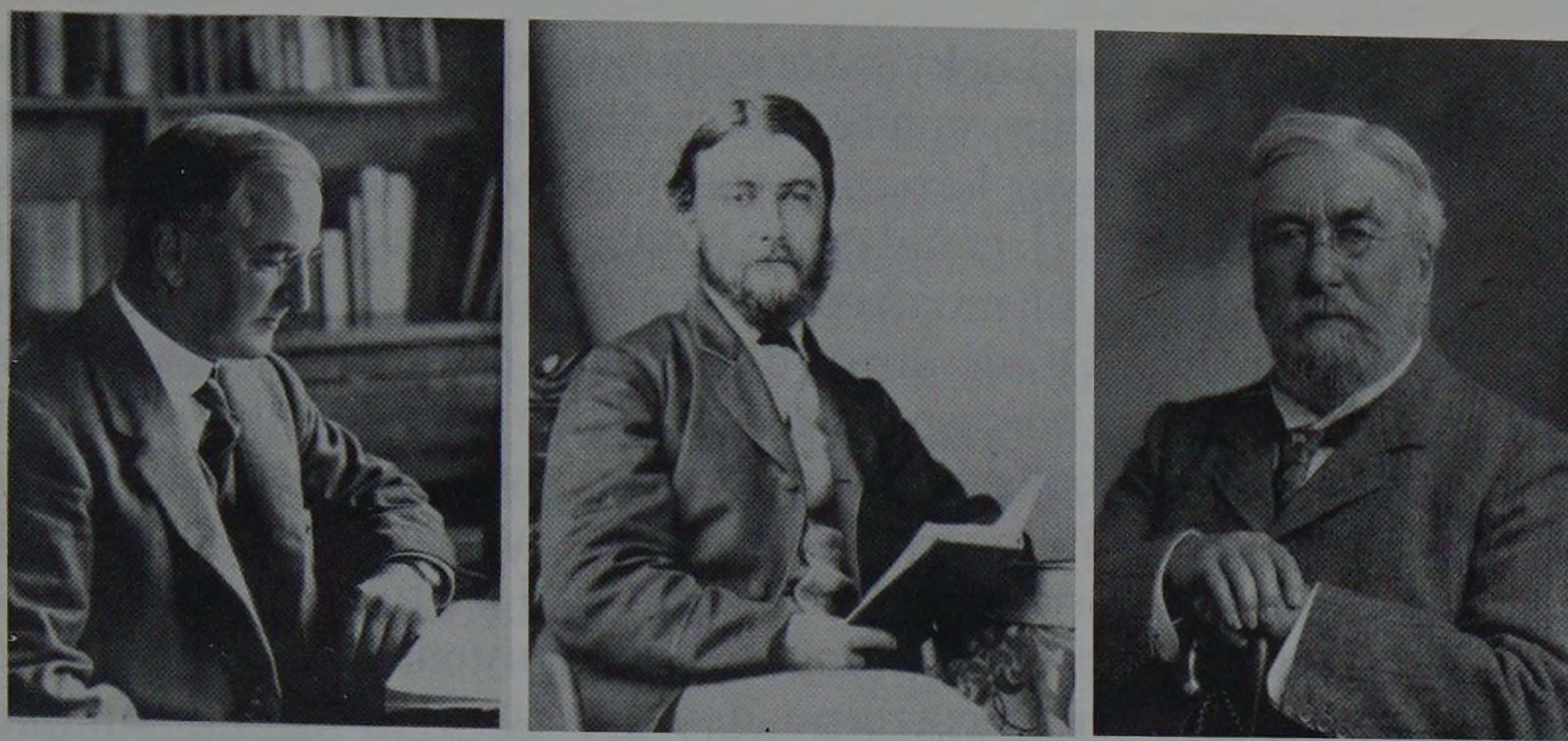

Figure 1. *Left:* based on a photo of W.J.S. Lockyer from a memorial booklet. *Middle:* early photo of Norman Lockyer (based on an RAS photo published in *Astronomy Now* in February 1999). *Right:* photo used as the frontispiece to the biography attributed to his wife and daughter.

Corporation was liquidated in 1992; its assets were distributed between the Royal Astronomical Society (for the Sir Norman Lockyer Memorial Trust), the East Devon District Council and the University of Exeter. At that time it was the intention that part of the archives should be transferred to the Science Museum at South Kensington, but in 1995 it was agreed that they should not be split, but that all should be cared for by the University.

The two amateur societies were given responsibility for the operation of the Observatory on condition that it was regularly opened to the public and to school groups. This was so successful that in 1995 the Council built a major addition to the Mond building for a planetarium and for exhibitions. At the same time the two societies combined to form the Norman Lockyer Observatory Society, which is now an educational charity. In 1996 a Meteorology Group was formed and regular observations are made. There is also a small history group and there is considerable interest in the local "Jurassic Coast", which was given the status of a World Heritage Site in 2002.

One of the conditions of the agreement with the Science Museum was that the University would prepare a catalogue of the archives. Consequently, I sorted and listed Norman Lockyer's pre-retirement correspondence, which was considered to be the most important part of the

archive. At this time the Lockyer correspondence and other early documents were kept in secure conditions in the main university library. At first I listed the Lockyer letters in the library, but progress was slow until it was agreed that I could take batches of letters home. I also obtained the assistance of members of the NLO Society in listing the correspondence of the Observatory during the pre-war period. I had found much of this later correspondence in a pile of assorted documents with the NLO library books, which were then 'awaiting disposal' in the basement of another building as the University had no interest in them. I obtained a reprieve for the collection and so I sorted the documents and gathered and re-shelved the books during my visits to the University. The listing of the NLO correspondence in the NLO files that I had saved was also done by the members of the Society in their homes.

All this voluntary activity came to end after the appointment of a new University Librarian as my direct access to the NLO library and the archives was denied when the standards of archival provision and care at the Library were upgraded and professionalised. My listing of the Lockyer correspondence was, however, sufficiently advanced for me to produce a few copies of the catalogue in February 2000. It had been

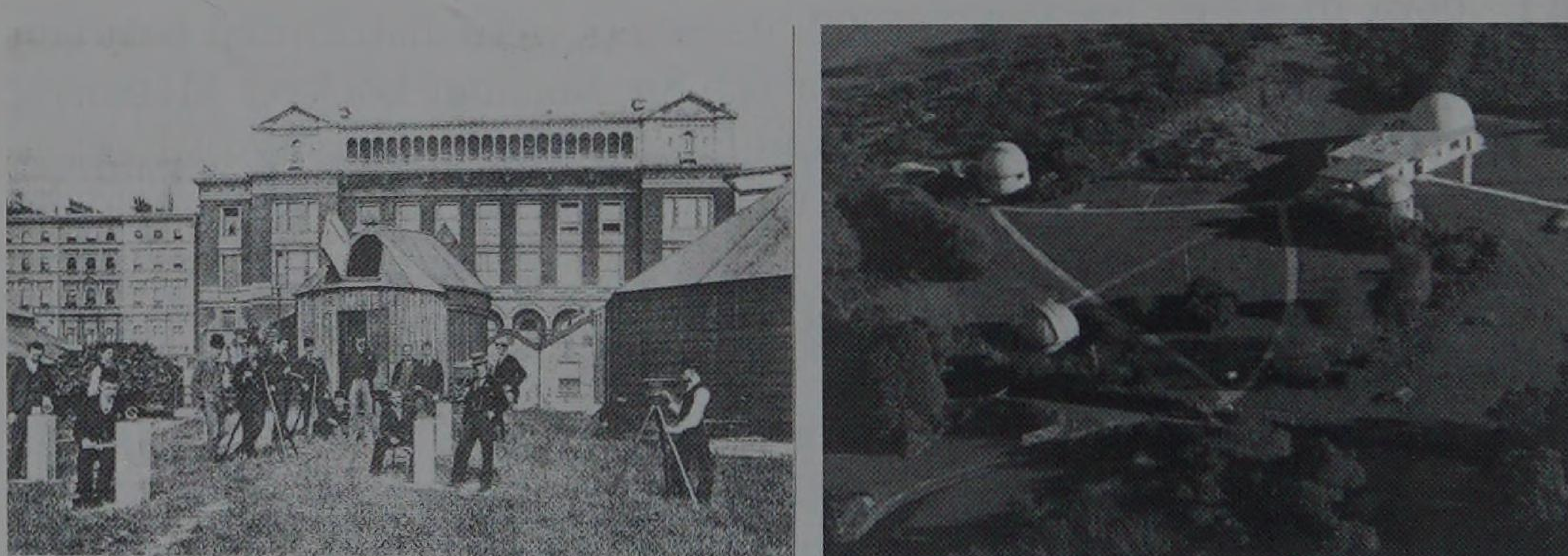

Figure 2. *Left:* part of the Solar Physics Observatory at South Kensington, with some students, in 1893. In the background is the building used by the Royal College of Science in which Lockyer was the Professor of Astronomical Physics. It became known as the Huxley Building from 1932, but it has been renamed since it was taken over by the adjacent Victoria and Albert Museum a few years ago. *Right:* NLO at Sidmouth, Devon, based on a colour photograph taken by John Dunkley, one of the members of the NLO Society, in 1995 after the opening of the extension for the planetarium.

the intention that the catalogue would be made widely available on the website of the University Library, but this was not done. A part-time archivist, Ian Mortimer, was, however, appointed and the archival material from both buildings was gathered together in a new secure environment in the Old Library building. He produced brief descriptions of two of the principal classes into which the material was divided and a 'rough handlist' of the NLO files and boxes of working papers that were transferred with the library from Sidmouth to Exeter. His place has since been taken by a full-time archivist, Charlotte Berry, who has already carried out a lot of additional work on these archives. In particular, full collection-level descriptions of the material are now available on the website. The catalogue of the Lockyer correspondence is available for use in the reading room for the Special Collections section of the Library. It is expected that detailed lists of all of the Lockyer collections will be made available on the Special Collections website in the future.

2. Principal Contents of the Archives

The archives are now held in three principal classes as follows.

EUL MS 110: Lockyer Research Papers, c1860–1920. The most important part of this class is the residue of the correspondence between Lockyer and over 900 correspondents. Unfortunately, it consists almost entirely of the letters received by Lockyer as it appears that he rarely kept even notes about his outgoing letters. I did, however, find in the Library of Congress a few letters written to Simon Newcomb and so there are copies of these in the collection. I would be glad to receive information about other such letters in the archives of other observatories and institutions. It is clear that many letters have been lost as there are some unlikely gaps in the correspondence; moreover, some of the letters referred to by Meadows (1972) in his biography of Lockyer could not be found. Luckily, Meadows had kept photocopies of many of them and these are now available. There are only a few letters relating to Lockyer's editorship of *Nature* or to the Solar Physics Observatory. Some notes on my catalogue are given below.

Amongst the remainder of the class are: eclipse notebooks; notes on lectures and addresses; papers relating to the Royal Commission on Scientific Instruction, of which he was secretary in 1871–1877; papers relating to the transfer of the Solar Physics Observatory from South Kensington to Cambridge in 1913; and personal papers relating to his

awards and honorary degrees. One interesting item is the observation notebook that he started in 1862 after he acquired the 16-cm refractor with which he carried out his early research, and which is still in use in the Observatory at Sidmouth. I found this by chance amongst the much later NLO observing notebooks in a storeroom in the university library.

EUL MS 72: Norman Lockyer Observatory Papers, c1913–1989. This class consists of two types of material. Firstly, there are correspondence files, reports and memoranda, account books, visitors' books, photographs of the observatory and individuals, and other items of an administrative and historical character. Secondly, there are the 'research files', most of which are boxes of assorted working papers whose value, if any, could only be assessed after a careful examination by someone familiar with the field, such as the observation of variable stars.

One particularly interesting item is the manuscript prepared by W.J.S. Lockyer for a book with the title *In thunderstorms with a camera.* He was a meteorologist (Wilkins and Wilson 1997), as well as being an astronomer and a keen amateur photographer. It is a pity that the last chapter is missing and that the book was not published. There is also a collection of reprints of his research papers, but not of the many articles that he wrote for *Nature.*

EUL MS 114: Papers of Norman Lockyer (RAS) c1876–c1969. These are papers relating to the Hill Observatory and the Norman Lockyer Observatory that were transferred (at my suggestion) to the university on long-term loan from the Royal Astronomical Society (RAS). They include a lot of administrative papers as they were given to the Society by a relative of W.N. McClean, who was treasurer of the Norman Lockyer Observatory Corporation for many years. They also contain some papers relating to the gift by his father, Frank McClean, of a telescope to the Royal Observatory at the Cape of Good Hope. There are also some smaller collections of relevant documents.

EUL MS 128: Papers relating to the Norman Lockyer Observatory, 1851–1985. These papers were passed to me by a retiring member of the Physics Department of the University, who had acted as the liaison officer between the Department and the Librarian at the Observatory at Sidmouth. Many of the documents relate to the day-to-day running of the Library, but in addition there are various items of more

general interest, such as a telegram that Marconi sent by 'ether waves' from Canada to Lockyer in 1903.

EUL MS 186: Lockyer Papers (Sid Vale collection), 1895. This contains a small group of letters that were given, at my suggestion, by the Sid Vale Heritage Centre in Sidmouth to the University. Three of them are from Sir William Ramsey, the discoverer of the inert gas helium, whose existence in the Sun had been postulated by Lockyer some 25 years earlier. The Centre has a display of various Lockyer memorabilia, such as medals, as well as photographs and publications.

EUL MS 236: Letters to Sir Norman Lockyer, 1869–1919. This small collection of letters was lent for use in the preparation of the centenary edition of *Nature* in 1969 and was returned by a private donor in 2001.

EUL MS 246: Financial papers of the Norman Lockyer Observatory, 1944–1966. These are papers that were generated in the University while it was funding the Corporation.

3. The Catalogue of the Lockyer Correspondence

When I first saw the Lockyer correspondence it was kept in a large number of brown paper envelopes in four main categories that related to the biography of Lockyer that was written by Herbert Dingle, but published under the names of Lockyer's wife and daughter (Lockyer, Lockyer and Dingle 1928). Correspondingly, the letters from one person were often scattered in several envelopes and so it was agreed that I should sort them into alphabetical order and by date. In general, I also sorted them by person rather than by institution, but cross-references are given in the catalogue where appropriate. Letters to other members of the family and various ephemera, such as newspaper cuttings and graphical items have been filed and listed separately from the main collection as 'Z-files'. For each letter I have usually given a brief description of the contents in a few lines. For many correspondents there is only one letter, but for some, such as F.C. Penrose, there are many letters over many years. This correspondence is now part of EUL MS 110. The principal correspondents in the catalogue are given in Table 1.

4. Other Related Sources

The University also holds some of the records of the amateur societies (mentioned above) that have used the Norman Lockyer Observatory

Table 1. Principal correspondents in the catalogue of the Lockyer correspondence in EUL MS 110.

Pages	Correspondents
A 1	Frederick A. Abel, George B. Airy, Edmund Antrobus, Lord Avebury
B 9	George Baden-Powell, William Black, British Association for the Advancement of Science, John Browning
C 22	William M. H. Christie, George J. Clarke, Agnes M. Clerke, William Crookes
D 31	Warren de la Rue, Henri Deslandres, Duke of Devonshire, John F. D. Donnelly, Henry Draper
E 40	John Eliot
F 44	Lazurus Fletcher, Michael Foster, Edward Frankland
G 54	Archibald Geikie, David Gill, Howard Grubb, Amédée V. Guillemin
H 63	Richard B. Haldane, George E. Hale, Alexander S. Herschel
H 71	John R. Hind, Joseph D. Hooker, William Huggins, Thomas H. Huxley
J 80	Jules Janssen
K 83	Lord Kelvin, G. King-Hall, George Knott, (Krakatoa)
L 88	Samuel P. Langley, Urbain J. J. Leverrier, William J. S. Lockyer, Henry G. Lyons
M 98	Charles Meldrum, James A. H. Murray
N 110	(Nature), Hugh F. Newall, Robert S. Newall, Simon Newcomb
P 116	Benjamin Pierce, Francis C. Penrose, Edward C. Pickering, (Prince of Wales), Charles Pritchard
R 135	William Ramsay, Isaac Roberts, Henry E. Roscoe, Royal Astronomical Society, Royal Society
S 145	Edwin L. Sambourne, G. M. Seabroke, William N. Shaw, C. William Siemens
S 155	C. Piazzi Smyth, Balfour Stewart, George G. Stokes, Alexander Strange
T 165	Peter G. Tait, J. F. Tennant, Alfred Tennyson, William T. Thistleton-Dyer, Herbert H. Turner
W 177	Thomas W. Webb, William J. L. Wharton
Y 185	Charles A. Young

from about 1973 onwards. These records were not, however, listed by Ian Mortimer. I understand that the University is reluctant to keep such records or to add to the collection and so I have (also reluctantly) stored at home other papers that I believe would be best kept at the University, where they would be in better conditions and could be made accessible to others.

It is probable that most of the papers generated at the University for the Norman Lockyer Observatory Corporation between 1948 and 1992 when it provided the secretary and most of the funding are held in the Devon Record Office, but I have not yet confirmed this.

The archives of the Imperial College at South Kensington contain papers relating to Lockyer's activities there, as well as letters that Lockyer wrote to T.H. Huxley.

The archives of the University of Leicester also contain much material relating to Lockyer and the Observatory at Sidmouth. This was collected by Professor A.J. Meadows at about the time of the publication of his biography of Lockyer. A manuscript list of the contents was made by David DeVorkin, who was then a student working with Meadows.

The Bodleian Library at the University of Oxford contains the archives of the British Association for the Advancement of Science (BAAS) and these include many papers relating to the British Science Guild, which was started by Lockyer in 1905 to encourage greater support for science by the government. Lady Lockyer continued to be active in the Guild until it merged with the BAAS in 1936.

The website of the National Register of Archives shows the existence of other correspondence and papers, including the letters to Sir David Gill at the Royal Geographical Society, the letters to Sir George Stokes at the Cambridge University Library, and the correspondence with Macmillan, the publisher of *Nature* and of Lockyer's astronomical books.

The archives of the Royal Greenwich Observatory, now in the Cambridge University Library, contain papers relating to the Norman Lockyer Observatory as both Dyson and Spencer Jones served on the Research Committee of the Observatory.

5. Photographic Plates

The Norman Lockyer Observatory Society has recently recovered from the Science Museum the photographic plates that were deposited there

when the Observatory was cleared at the time of the sale in 1986 (see White 2003.) There are nearly 8000 glass negatives, of which over 6000 are of stellar spectra. Some are from the 19th century, while others are from the Observatory at Sidmouth, when a special study was made of variable stars, such as γ Cassiopeiae. A catalogue will be made available on the NLO website. There are also some lantern slides that were used for lectures (see Ponsford 2003).

Contact at the University of Exeter

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website:`http:// www.library.ex.ac.uk/special/`

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Part 2

HISTORICAL TRANSITS OF VENUS

Recognizing the historical importance of previous transits of Venus and the numerous transit of Venus expeditions mounted by various countries, and Noting the rarity of the upcoming transits in 2004 and 2012 Commission 41 Recommends that the sites of previous transit of Venus expeditions be inventoried, marked and preserved, as well as instrumentation and documents associated with these expeditions.

IAU Resolution (2000 General Assembly)

ASTRONOMICAL HERITAGES: Astronomical Archives and Historic Transits of Venus
Journal of Astronomical Data, Vol. 10, 7, 2004
Christiaan Sterken, Hilmar W. Duerbeck, eds.

Maximilian Hell and the Northernmost Transit of Venus Expedition of 1769

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Abstract

A short biography of the Jesuit astronomer Maximilian Hell (1720–1792), founder and director of the Astronomical Observatory in Vienna and editor of the Viennese Astronomical Almanac is presented. He was the leader of the expedition to Vardö Island for observing the transit of Venus of 1769. The journey of the participants, the preparations for observing the important phenomenon and its successful observations are described. Hell's scientific merits won him the membership in several European Academies, and his name is found on lunar maps.

1. Introduction

Among the many expeditions which were organised in order to observe this rare phenomenon in 1769 was the one to Vardö, which was led by Maximilian Hell, director of the Astronomical Observatory in Vienna.

Maximilian Hell (Fig. 1) was born on May 15, 1720 in Bánska Štiavnica, Slovakia[1], where his father, Matei Kornel Hell, who was originally from Bohemia, had established himself as a mine engineer. Maximilian grew up into a family environment which favoured the development of his technical skills. He attended the local school in his native town and at Bánska Bystrica as well, where he graduated from the secondary school in 1738. In the same year, he joined the Jesuit Order in Trenčín (German Trentschin), where he made his noviciate. He studied philosophy, mathematics, and astronomy in Vienna, and assisted

[1]Schemnitz in German, since Slovakia belonged at that time to Austria-Hungary.

in the observations of Joseph Franz, the director of the Jesuit Observatory, and in the organization of a museum of experimental physics. He later also studied theology, and the order entrusted to him some missions. As a teacher of humanities at the secondary school in Levoče (Slovakia) (German Leutschau), he founded an astronomical observatory at Trnava (Slovakia). He stayed for three years as a mathematics teacher at the Jesuit College in Cluj (German Klausenburg, Transylvania), where he published two manuals: *Elementa mathematica naturali philosophiae Ancillantia ad Praefixam in Scolis nostris normam. Tomulus I. Elementa Arithmeticae numericae & literalis seu Algebra,* and *Exercitationes mathematicarum. Pars I. Exercitationes arithmeticae.*

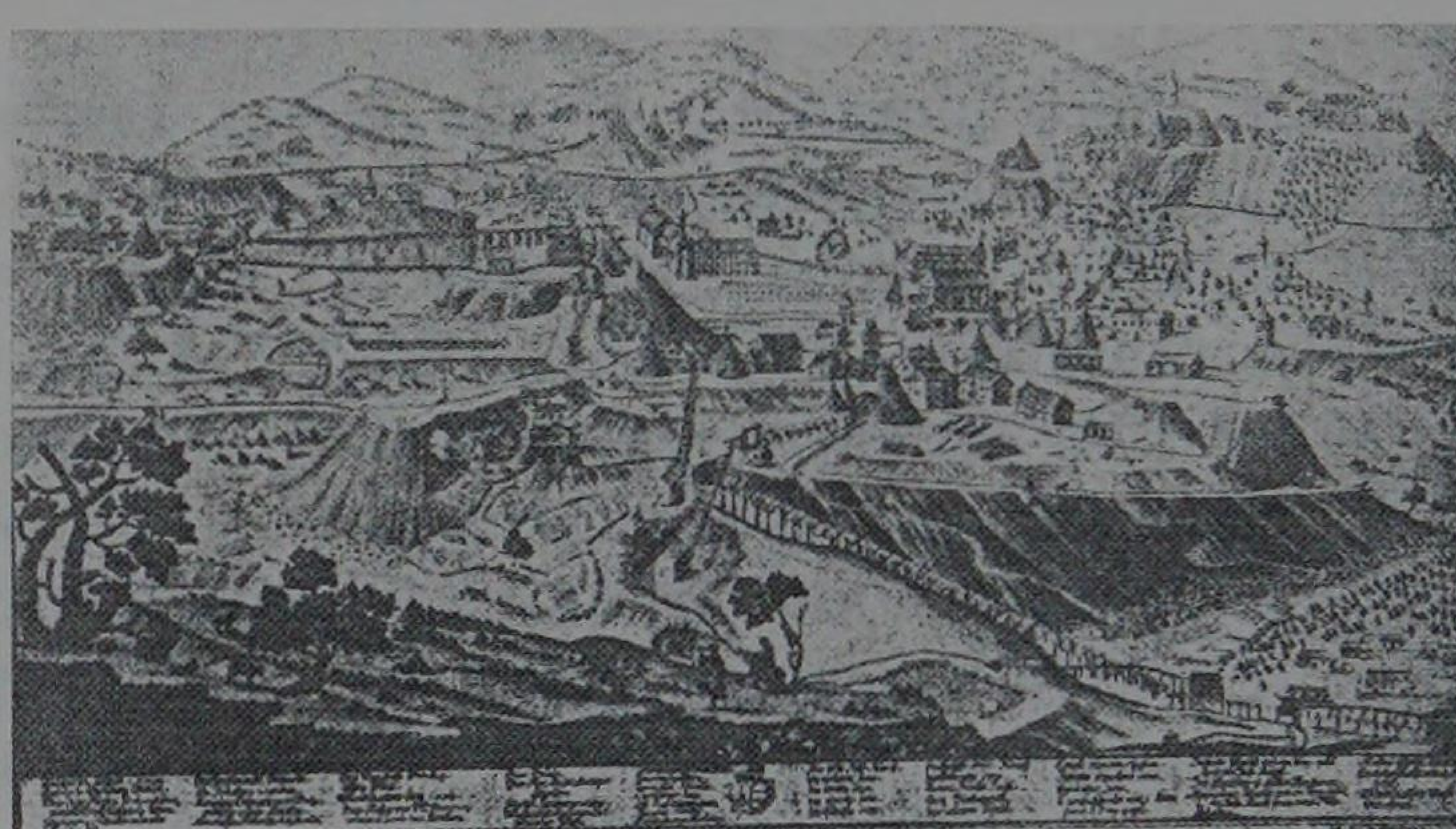
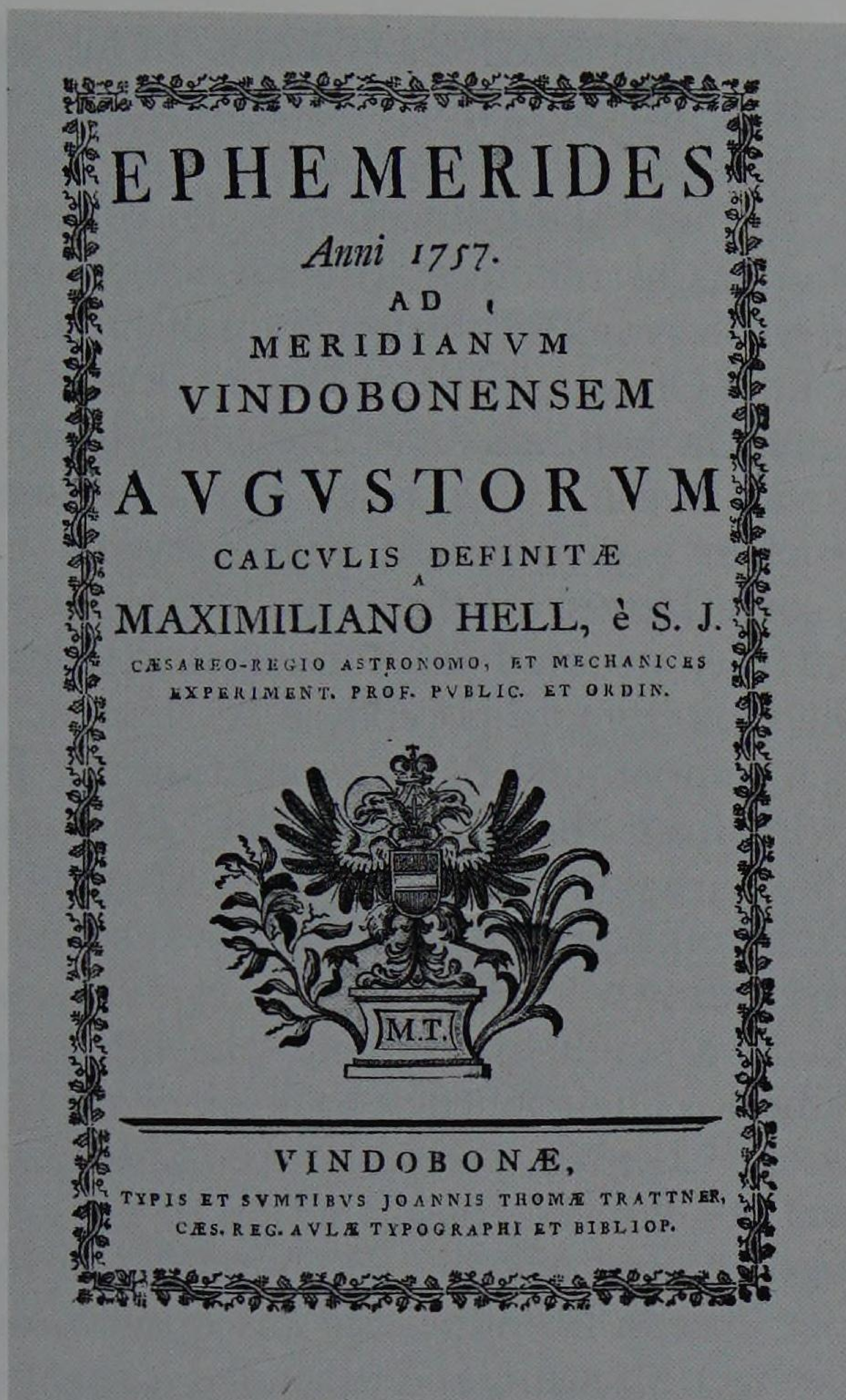


Figure 1. *Left:* Maximilian Hell (1720–1792). *Right:* Bánska Štiavnica at that time, Hell's native town.

When he returned to Vienna in 1755, almost his entire future activity would be dedicated to astronomy. He founded the Astronomical Observatory of the Viennese University, becoming its life-long director, and was paid 300 golden crowns per year. He was in charge of the institute building, was in charge of making regular astronomical observations and reducing them, maintaining connections with the international scientific world, teaching every Sunday a lesson of astronomy in the amphitheatre of the Faculty of Philosophy, and publishing the results of astronomical observations and studies.

A short time after the Astronomical Observatory was founded, he issued the first almanac *Ephemerides astronomicae anni 1757 ad meridianum Vindobonensem*[2] (Fig. 2), which he would publish every

[2]10 years before the *Nautical Almanac.*


EPHEMERIDES
Anni 1757.
AD
MERIDIANVM
VINDOBONENSEM
AVGVSTORVM
CALCVLIS DEFINITÆ
A
MAXIMILIANO HELL, è S. J.
CÆSAREO-REGIO ASTRONOMO, ET MECHANICES
EXPERIMENT. PROF. PVBLIC. ET ORDIN.

M.T.

VINDOBONÆ,
TYPIS ET SVMTIBVS JOANNIS THOMÆ TRATTNER,
CÆS. REG. AVLÆ TYPOGRAPHI ET BIBLIOP.

Figure 2. Title page of the first Viennese Astronomical Almanac.

year until 1786 (except in the years he was absent from the country, when it was edited by Anton Pilgram), and in which pages his observations were published as well as those of other foreign astronomers.

2. The Transit of Venus Expedition

The most important astronomical event of his life was the transit of Venus on June 3, 1769. Hell showed a great interest in this phenomenon, and even published in the Viennese almanac a memoir concerning the previous transit *De singulari phoenomeno Transitus Veneris per discum Solis die 5 Junii 1761.* In the astronomical world, a polemic was

evolving about the so-called satellite of Venus. In his work *De satellite Veneris* he showed that "the satellite" which some astronomers claimed to have observed is just the secondary image of the very brilliant image of the planet, reflected into the telescope by the cornea of the eye.

As a world-famous astronomer, Hell received many proposals to lead an expedition to observe the phenomenon of 1769, and he accepted the one offered by king Christian VII of Denmark and Norway through his messenger, count Bachoff, an expedition which would be financed by the Danish Royal House. This royal financing suggests the high costs entailed by such an expedition. It was necessary that queen Maria Theresa assented, something she did gladly. The place where the transit would be observed was situated in Norwegian Lapland, beyond the Polar Circle, in the most remote populated settlement, Vardö Island.

Hell chose as a companion in this expedition the Jesuit Jan János (Johannes) Sajnovics from the Astronomical Observatory in Trnava, who would keep the journal of the expedition. After an audience at the Viennese Royal Court on April 28, 1768, the two scientists started the journey in a carriage drawn by four horses, carrying with them their personal luggage and a small instrument, the big instruments being sent directly to Lübeck. Their journey took place on the route Prague – Dresden – Meissen – Leipzig – Hamburg – Lübeck to Copenhagen (Fig. 4). The scientists enjoyed the attention of personalities in these towns and visited some institutions and churches. In Prague they visited the astronomer Joseph Stepling and his observatory. In Dresden they visited the Zwinger Museum and attended a theatre performance. In Meissen they visited the famous porcelain factory and in Leipzig, at the University, they met prominent personalities like the professor of mathematics Gottfried Heinsius who, before settling in Leipzig, had been an astronomer at the Observatory of Sankt Petersburg.

They were welcomed at Copenhagen and after a short sojourn they were transported to the Swedish border in three post-chaises together with the astronomical instruments from Vienna, to which were added those borrowed from the Astronomical Observatory of Copenhagen. During this trip they were accompanied by the director of the observatory himself, Christian Horrebow. Then they crossed the Swedish land and crossed the border to Norway. At Christiania (Oslo) they were enthusiastically celebrated. Their astronomical observations showed that the latitude of the settlement was two degrees less than indicated on the maps. Crossing Miösen See, they reached Trondjem where they determined the latitude. From this point, the expedition was enlarged with the governor of the Finnmark province, the young Danish student

Figure 3. Map of the expedition itinerary.

Borgrewing, a cook, two servants and four sailors, and they embarked on a very well equipped ship. Following the king's advice they were provided with means of living for one year.

The trip proceeded on the water, having both good weather and also storms, which retained them on the land where they explored the

fauna and flora of the marine coast and measured the geographical latitudes. On October 11 they arrived at Vardö Island, the observation location proposed by the Danish king, and were welcomed by the governor, the vicar, the local garrison and the population. In this northern settlement where the Sun remains above the horizon for two months around summer solstice and for two below the horizon around winter solstice, they immediately began building an observatory, a job mainly done by the light of torches. They built a gnomon and a thin wall that marked the meridian of the place. They installed the clocks (from Vienna and Copenhagen) which were very well protected in order to avoid damage from the salty humidity of the ocean, and on June 2, 3 and 4, their running was carefully controlled. Using the equal altitude method, aided by a gnomon, they determined apparent noon on June 3 and 4. The precise location of the observatory was determined by the quadrant, the astronomers observing pairs of stars with known declinations, which culminated at the almost same altitude; thus they determined the latitude of $70°22'35''$, and the longitude, $28°46'30''$ with respect to the meridian of Paris Observatory, and $48°40'15''$ with respect to the first meridian of Ferro.

The observations of the transit were carefully prepared, and should be done by Hell, Sajnovics and Borgrewing with three different telescopes, equipped with diaphragms. The week before the transit was completely clouded and did not give them high hopes. But on June 3, the weather improved and the immersion of the planet on the solar disk was almost simultaneously reported by Sajnovics and Borgrewing. But since the moment of the first external contact was impossible to observe, Hell, estimating the time needed by the planet for traversing an arcsecond in its motion to be 15 seconds of time, deduced that it must have happened 30 seconds before the report. Then Hell observed the first internal contact with the achromatic 10 feet Dollond telescope, Sajnovics with the $10\frac{1}{2}$-feet telescope, and Borgrewing with the $8\frac{1}{2}$-feet telescope equipped with a micrometer.

Then they compared the two clocks, and permitted the entry of visitors to the observatory to contemplate – with necessary caution – the planet Venus situated entirely in front of the Sun.

During the time between the second and third transits, the weather became unfavourable, but before third contact the sky became clear and they could observe under good conditions, even the visitors had the possibility to follow the phenomena. The two Jesuits attributed this unexpected clearing of the sky, which allowed them to observe completely the phenomenon, to God's mercy.

3. The Results of the Expedition

The four contact observations are summarized in Fig. 4. The observing of the four contacts was the main result of Hell's expedition, the cannon of Vardö fortress announcing it as an important event. The Jesuits left the island on June 27, the report of the expedition was presented at the Academy of Copenhagen in November and published the following February (*Observatio Transitus Veneris Ante Discum Solis Die Junii Anno 1769 Wardoehusii*, see Fig. 5).

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Conſpectus

Obſervationum contactuum limbi Veneris, cum limbis Solis.

In Ingreſſu.	Temp. horologii Vienenſis. h. ′. ″.	Reductio ad Temp. Ver. Adde. ′. ″.	Tempus Verum. h. ′. ″.
Temporis momentum a P. Sajnovics, & D. Borgrewing in ingreſſu exteriore obſervatum, quo particula aliqua diametri Veneris in limbum Solis jam ingreſſa cernebatur	9. 15. 17.	1. 22. 8.	9. 16. 39. 8.
Ego particulam hanc æſtimans eſſe duorum circiter Secundorum circuli, arbitratus ſum, contactum primum externum, obſervatu impoſſibilem evenire debuiſſe 30″ temporis citius, hoc eſt tempore .	9. 14. 47.	1. 22. 8.	9. 16. 9. 8.
Ego Tubo Achromatico judico limbum Veneris formam ſuam circularem in ingreſſu fere obtinere	9. 32. 35.	1. 22. 6.	9. 33. 57. 6.
(*) Cenſeo circumferentias Veneris & Solis perfecte jam circulares, neque tamen adhuc filum lucidum Solis apparet	9. 32. 42.	1. 22. 6.	9. 34. 4. 6.
(**) Apparet filum lucidum limbi Solis Venere jam totaliter ingreſſa .	9. 32. 48.	1. 22. 6.	9. 34. 10. 6.
P. Sajnovics, videtur Venus circumferentiam ſuam integram recuperare	9. 32. 30.	1. 22. 6.	9. 33. 52. 6.
Ingreſſus totalis Veneris filo lucido Solis apparente	9. 32. 45.	1. 22. 6.	9. 34. 7. 6.
D. Borgrewing ingreſſus totalis Veneris	9. 33. 10.	1. 22. 6.	9. 34. 32. 6.
Altitudo apparens limbi Solis, in quo Venus totaliter ingreſſa erat 6°. 33′.			

In

(*) Aliqui Obſervatores hoc momentum habent pro contactu interiori in ingreſſu.
(**) Alii contra Obſervatores hoc momentum vocant contactum interiorem, utrique haud recte, prout ſupra demonſtravi.

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In Egreſſu.	Temp. horologii Vienenſis. h. ′. ″.	Reductio ad Temp. Ver. Adde. ′. ″.	Tempus Verum. h. ′. ″.
Ego (Tubo Achromatico) appropinquante limbo Veneris ad limbum Solis, video, veluti guttam nigram intra limbum obſcurum Veneris, & lucidum Solis formari (Vid. Fig. II. A.) . .	15. 26. 6.	1. 18. 6.	15. 27. 24. 6.
Cerno guttam hanc imminui .	15. 26. 12.	1. 18. 6.	15. 27. 30. 6.
Gutta hæc momentanee diſparet, & veluti diffluit, limbusque Solis & Veneris in unum confluunt, atque adeo contactus verus opticus in egreſſu	15. 26. 17.	1. 18. 6.	15. 27. 35. 6.
P. Sajnovics Tubo 10 & ½ ped. contactus internus certus	15. 26. 18.	1. 18. 6.	15. 27. 36. 6.
D. Borgrewing Tubo 8½ ped. contactus	15. 26. 10.	1. 18. 6.	15. 27. 28. 6.
Altitudo apparens limbi Solis, ad quem Venus egrediens verſabatur, erat 9°. 43′.			
Egreſſus totalis Veneris Tubo Achromatico mihi dubius .	15. 44. 22.	1. 18. 4.	15. 45. 40. 4.
Mihi certus . .	15. 44. 26.	1. 18. 4.	15. 45. 44. 4.
P. Sajnovics egreſſus totalis certus	15. 44. 27.	1. 18. 4.	15. 45. 45. 4.
D. Borgrewing egreſſus totalis .	15. 44. 20.	1. 18. 4.	15. 45. 38. 4.
Altitudo apparens limbi Solis ad quem Venus egreſſa eſt = 10°. 4′. 0″.			

Notandum. Obſervationem D. Borgrewing, etſi a mea & P. Sajnovics differentem, eſſe tamen conformem effectui Tubi, quem adhibuit, quo omnino contactum interiorem in ingreſſu ſerius, in egreſſu vero citius videre debuit.

Habentur

Figure 4. The table summarizing the contact observations.

But its result was not in agreement with those of other observers, respectively, the value of the parallax of the Sun deduced from the inclusion of this transit in *De parallaxe Solis ex observationibus transitus Veneris anni 1769* which proved to be the most accurate at that time. The delay with which Hell made known the result of the expedition stirred the suspicion of Joseph Jérôme de Lalande, who made himself the promotor of the missions made on the occasion of this astronomical event in front of European governors. He was not aware of Hell's expedition (the Danish Court wishing to keep this mission a secret) until the moment when the report was presented to the king. Lalande

objected against the result obtained by Hell, but he withdraw his criticism, publishing after the latter's death (with whom he had meanwhile reconciled) a panegyric where he wrote:

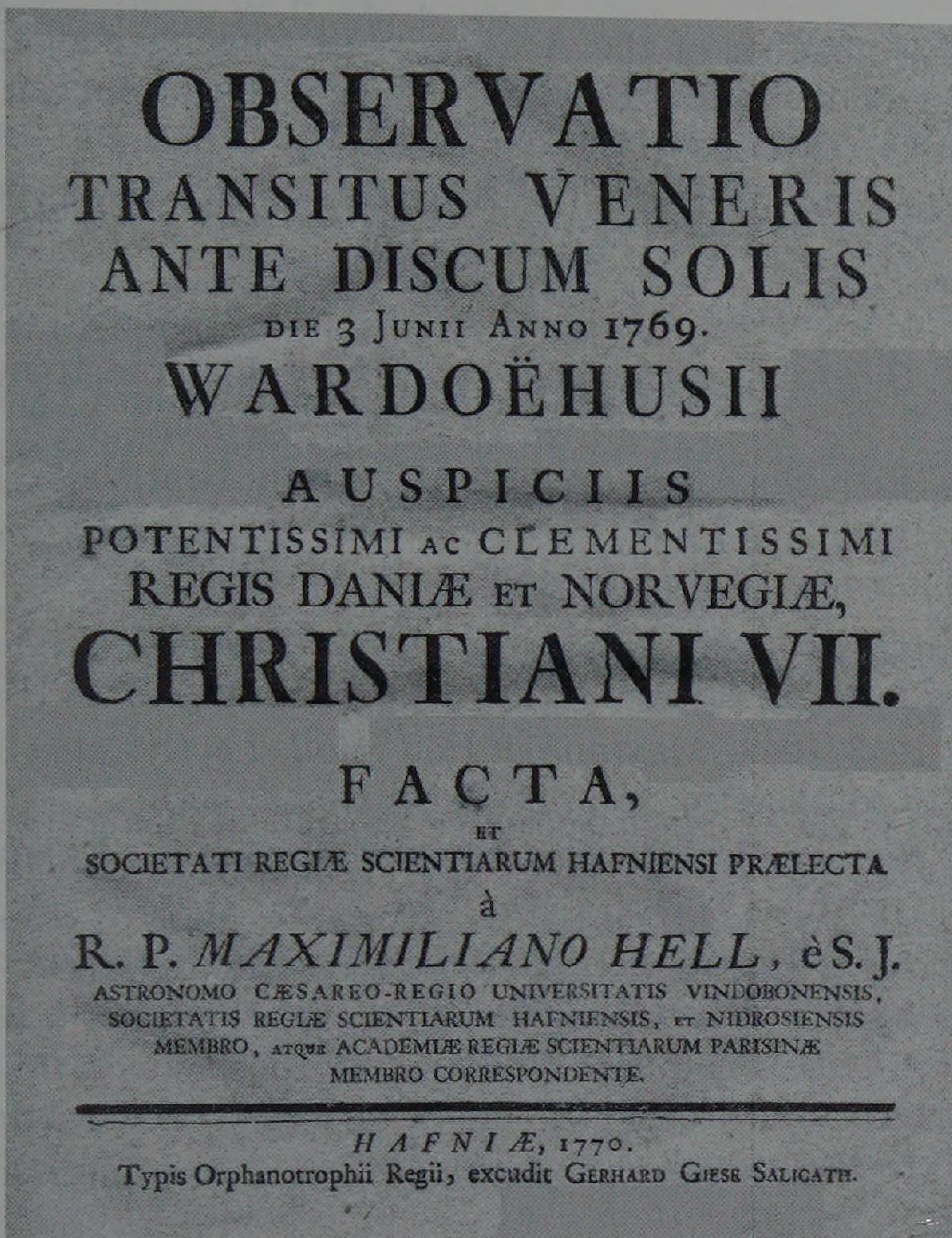
> "L'observation du P. Hell réussit complètement, elle s'est trouvée une des cinq observations complètes faites à de grandes distances, et où l'éloignement de Vénus changeant le plus la durée du passage, nous a fait connaître la véritable distance du Soleil et de toutes les planètes à la Terre".

However, the suspicion still remained in Johann Franz Encke's publication of 1824 *Der Venus-Durchgang von 1769*, and in 1835 Carl Ludwig von Littrow, assistant at the Astronomical Observatory of the Viennese University published the translation in German of Sajnovics' journal and, strange enough, used this opportunity to attack the integrity of Hell, saying that the latter had corrected his observations in order to make them agree with the best values found. This accusation was removed only in 1883 by Simon Newcomb, himself an observer of the transits of 1874 and 1882. When he came to Vienna to examine the new telescope, during cloudy nights he searched in the observatory's library for Hell's original manuscripts, and upon inspection became convinced that the correction of the data in the manuscript was not a subsequent one, but done on location. Newcomb published his findings in Monthly Notices, May, 1883.

After an absence from the country of two years and 3 months, Hell came back to Vienna on August 12, 1770. The extremely poor weather conditions during his stay at Vardö did not prevent the skilful researcher from taking care of many other problems to which this unique circumstance of his life opened the way. In this poorly known northern region, everything was interesting, and Hell studied magnetism, the tides, the winds, etc. He wanted to present the results of the expedition in a work *Expeditio litteraria ad polum arcticum*, but the suppression of his order in 1773 foiled this intention. Part of the observational material that he had gathered served to elaborate a new theory about the aurora borealis, which he published in 1776 (*Aurorae Borealis theoria nova*).

4. Hell's Remaining Years

In Vienna, Hell resumed his former activities. He also participated in the debates about building an Astronomical Observatory at the High School in Eger (Hungary), and he planned the establishment of an



OBSERVATIO
TRANSITUS VENERIS
ANTE DISCUM SOLIS
DIE 3 JUNII ANNO 1769.
WARDOËHUSII
AUSPICIIS
POTENTISSIMI AC CLEMENTISSIMI
REGIS DANIÆ ET NORVEGIÆ,
CHRISTIANI VII.
FACTA,
ET
SOCIETATI REGIÆ SCIENTIARUM HAFNIENSI PRÆLECTA
à
R. P. *MAXIMILIANO HELL*, è S. J.
ASTRONOMO CÆSAREO-REGIO UNIVERSITATIS VINDOBONENSIS,
SOCIETATIS REGIÆ SCIENTIARUM HAFNIENSIS, ET NIDROSIENSIS
MEMBRO, ATQUE ACADEMIÆ REGIÆ SCIENTIARUM PARISINÆ
MEMBRO CORRESPONDENTE.

HAFNIÆ, 1770.
Typis Orphanotrophii Regii, excudit GERHARD GIESE SALICATH.

Figure 5. Title page of the work presenting the results of the expedition to Vardö Island.

Academy of Science under the leadership of the Jesuits, but the order being suppressed, the idea was given up. Also, when the University was moved from Bratislava to Buda, Hell chose the location for the Astronomical Observatory.

After enjoying a very good health, on April 14, 1792 he died from pneumonia and was buried at Enzersdorf near Vienna. His scientific work contains 26 memoirs and was almost entirely written in Latin.

Maximilian Hell, whose character traits were the love for mankind and humanitarism, manifested a great tolerance towards the Protestants. As a scientist he enjoyed the appreciation of his contemporaries, becoming a corresponding member of the Academy of Sciences of Paris

and an active member of the Academies of Copenhagen, Göttingen, Stockholm, Trondheim and Bologna. As his highest homage, his name was attributed to a lunar crater.

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ASTRONOMICAL HERITAGES: Astronomical Archives and Historic Transits of Venus
Journal of Astronomical Data, Vol. 10, 7, 2004
Christiaan Sterken, Hilmar W. Duerbeck, eds.

Austria's Scientific Contribution to the Observation of the 1874 Transit of Venus

Martin Kopper

Excerpt from a diploma thesis, section History, submitted to the Geistes- und Kulturwissenschaftliche Fakultät der Universität Wien, Univ.-Prof. Dr. Helmuth Grössing.

Translation by Hilmar W. Duerbeck

Abstract

Already since the mid-19th century, it was a task of the Imperial-Royal Austro-Hungarian Navy not only to take part in military actions, to train sea cadets, to strengthen diplomatic relations, and to protect the coasts, the sea trade, and Austrian citizens in far countries, but also to carry out coast surveys and soundings, as well as scientific observations during their missions. On a trip around the Earth, Tobias von Österreicher, commander of the corvette *Erzherzog Friedrich*, was instructed to observe the Venus transit of December 8, 1874 in Yokohama. This order was only one out of many that he had to fulfill: to train the Navy cadets, to explore the possibility of the installation of a colony on the island of Borneo, to meet diplomats and consulate representatives, to carry out soundings and coast surveys to improve sea-charts, and to make meteorological observations. The "qualification list" indicates that all these tasks were fulfilled according to expectations. However, an incident on Borneo in 1875 took the life of two of his sailors. In its aftermath he did not react according to rules, he was reproached by the Navy Section of the Imperial War Ministry, and his career as a ship commander came to an end. Besides the Austrian expedition to observe the Venus transit of 1874 in Yokohama, a second one was carried out by the astronomers Eduard Weiss and Theodor Oppolzer in Jassy (Romania), which was supported by the Vienna Academy of Sciences.

1. The Most Important Travels of the k.k. Navy Connected to Scientific Tasks

Already in the years 1754–59, Nikolaus Freiherr von Jacquin undertook a research trip on behalf of Emperor Franz I Stephan and Empress Maria Theresia, which took him to Martinique, Haiti and Jamaica. Jacquin was born in 1727 in the Netherlands, was a doctor of medicine and a botanist, and had come to Vienna for completing his studies. He had become acquainted with the Emperor through his activity in the botanical gardens of Schönbrunn. Franz I Stephan, like many rulers of his time, wanted to have raised the most exotic and rare plants. For this reason, Jacquin was put in charge of a scientific expedition to tropical central America to collect fragrant plants, living animals, songbirds and waterfowl, shells, minerals and precious stones. In spite of many difficulties – deficient equipment, yellow fever, pirates – he succeeded in sending several shipments to Vienna, at first seeds, fossils, living shoots, afterwards whole tropical trees, corals, minerals, and finally, upon his return, a large number of living animals. These collections were brought to the greenhouses and the parc of Schönbrunn, and the botanical garden of Vienna. Jacquin's achievement during this research trip, which had lasted for five years and seven months, made him immediately a world-famous botanist (Petz 1993, p. 1–10).

The travels of the frigates *Austria* and *Principessa Augusta* that belonged to the Austro-Portuguese squadron brought enormous additions to the collections of natural history of the court. The principal task of the two ships was to to bring, in 1817, the daughter of Emperor Franz I with her escort from Livorno to Rio de Janeiro to meet her future husband, who would later become emperor Pedro I of Brazil. But from the beginning, the trip had been planned to also include scientific work, to explore unknown parts of Brazil, and to expand the natural history collections in Vienna. A group of specialists – from Austria and other countries – participated: botanists, zoologists, mineralogists and even painters, to record the impressions of the far land. Several shipments of many thousands of specimens were brought to Europe. Since space in the Vienna collections was not sufficient, the *Brazilian Museum* was founded as a unique documentation of the newly explored country (Hamann 1980, p. 61–63).

The scientific activity of the Austrian Navy culminated in the Earth circumsailing by the frigate *Novara* in 1857–59, in which the Academy of Sciences, which had been founded in 1847, took an active part. Archduke Ferdinand Max, at that time chief commander of the

Navy, took into consideration a trip to India and China, first for military training, and second, for a fostering of Austrian trade. Bernhard Freiherr von Wüllerstorff-Urbair was chosen as the commander, and he persuaded Ferdinand Max to arrange the trip as a circumnavigation of the Earth, and to invite scientists to participate. The Academy of Sciences was asked to select appropriate scientists, and the geologist Ferdinand Ritter von Hochstätter, the later organizer of the Vienna Museum of Natural History, and the zoologist Georg Ritter von Frauenfeld were chosen. Both were equipped by the Academy with "Notes and Directives" as well as with 13,000 fl. silver coinage as subsistence, and left Trieste on April 30, 1857 on board the *Novara.* Other well-known experts who had joined the expedition were: Karl von Scherzer, geographer and ethnologist, Dr. Eduard Schwarz, ship doctor and expert for tropical diseases, and Josef Selleny, landscape painter. Commander von Wüllerstorff-Urbair was a scientist himself, since he had studied astronomy in Vienna and had been director at the Naval Observatory, as well as professor at the Naval Academy. He supervised all oceanographic, hydrographic and meteorological observations.

The trip went to Rio de Janeiro, then to China, Australia, Tahiti and finally to Valparaiso. During the expedition, regular nautico-physical and magnetic observations were carried out and meteorological and hydrographical data were recorded, which were later published by the Hydrographic Institute of the k.k.[1] Navy (Meister 1947, p. 95–96).

Starting from the landing-places, expeditions inland were made to study geographic, geological, botanical, zoological and ethnological facts. The zoological collections of this trip comprise 26,000 specimens, the botanical ones extensive herbaria and seed collections, the mineralogical ones several thousand specimens, the ethnological ones 376 objects, and the anthropological collection more than 100 cranes of different human races (von Scherzer 1870, p. 617–618).

When the *Novara* arrived in Chile in April, 1859, commander von Wüllerstorff-Urbair learned about the pending war with France, and decided to return home immediately. There was no attack of the enemy on the Atlantic crossing, and when he arrived home, he learned that emperor Napoleon III had declared the *Novara* as a neutral ship, since

[1]k.k. Navy is used here as the abbreviation for the Imperial-Royal Austro-Hungarian Navy, a term used from 1867 onward. In 1889, the name was changed to k.u.k. Kriegsmarine, i.e. Imperial and Royal Austro-Hungarian Navy. Within the Dual Monarchy, foreign affairs and the major issues of defence were dealt with jointly by the Delegations, nominees of the two parliaments in Vienna and Budapest.

...she carries scientific treasures, and science is common property of all peoples on Earth (Sokol 1972, p. 93).

The elaboration and edition of the scientific results of the circumnavigation of the Earth was transferred, by the emperor's personal command, to the Academy of Sciences. It took 13 years until the complete work *Reise der österreichischen Fregatte Novara um die Erde in den Jahren 1857, 1858, 1859 unter den Befehlen des Commodore Bernhard von Wüllerstorf-Urbair* could be published in 21 volumes. The contents cover nautical-physical, geological, botanical, zoological, anthropological, ethnographical, linguistic, medical and statistical-commercial topics (Meister 1947, p. 96).

World politics at that time till the end of the 19th century was focussed on imperialism and colonialism. All European countries, especially the British and the French, were eager to found colonies in Africa and Asia. Before World War I, Europeans ruled 85% of all inhabited regions. Behind this wish for extra-European properties was the striving for economic expansion, the search for new sources of raw materials, new markets, and new room for a growing population. Austria did not belong to the colonial powers, but it was interested in expanding its foreign missions. More and more trips of the k.k. Navy were used to take over civilian tasks, scientific research, and economic orders (Basch-Ritter 1987, p. 76).

At the time when the *Novara* sailed around the world, the corvette *Carolina* was on her way to Brazil, to the La-Plata states, and to Africa. These were the last trips made by pure sailing ships of the k.k. Navy (Hassinger 1950, p. 150).

In 1869, emperor Franz Joseph with his escort undertook a trip to attend the opening of the Suez canal, to absolve an overdue state visit with the sultan of Constantinople, and to visit the pilgrim places in the Holy Land. This trip reflected the importance of Austria-Hungary, indicated its position in the circle of European naval powers, and was important for the commercial interests of the Habsburg monarchy. The time was, however, determined by the completion of the Suez canal, whose planning was done also by the Austrian engineer Alois Negrelli, among others (Basch-Ritter 1987, p. 78–83, Deihsen 1993).

The idea to connect the Mediterranean Sea with the Red Sea was already contemplated in antiquity. Investigations ordered by Napoleon led to no substantial result. Instigated by Metternich, new examinations were carried out in 1847. The Austrian engineer Alois Negrelli von Montelbe put forth plans for the construction of a canal without locks through the isthmus of Suez. His proposal was accepted, and he

was appointed inspector general by Egypt. He died in 1858, and the construction was carried out by the Frenchman Vicomte de Lesseps according to Negrelli's plans. Lesseps was honoured by a large monument at the entrance of Port Said, while Negrelli's name is almost forgotten (Wallisch 1956, p. 112–113).

In 1869, the commission installed by the Austrian Academy of Sciences for the investigation of the Adriatic Sea contacted the k.k. Central Authority in Trieste, asking to carry out meteorological observations on board the ships of the k.k. Navy, as well as on those of the Austrian Lloyd Trieste. Obviously it had become clear that too little had been undertaken in this field, especially in the Levant and the Black Sea (Archiv für Seewesen, Vol. 5, issue 11, p. 355, 1869).

The ships *Donau* and *Erzherzog Friedrich* departed in 1871 to the Far East in order to conclude commercial and nautical agreements, by which Austrian merchant ships should be put at equal footing with those of other seafaring nations. The representative of the Austrian Government was cabinet council Karl von Scherzer, who had already taken over important tasks on the *Novara*, and who had signed the agreements with Siam, China and Japan. The *Erzherzog Friedrich* returned to her port of registry via Suez, while the *Donau* headed for the Americas. The trip was an important commercial and nautical success. The scientific harvest was also rich, and enlarged the scientific results of the *Novara* expedition (Hamann 1980, p. 69).

At the end of the 1860s, the circumnavigations of the Earth and other trips to the hot and moderate regions had come to a conclusion. All members of the large Franklin expedition headed in 1847/48 to the polar region, lost their life, and this led to a certain reluctance to carry out further expeditions. Only the polar researcher August Petermann was able to focus the interest of the public at large to a new project. His idea was that because of the ramifications of the Gulf Stream, the Polar Sea should be navigable to the north much farther than on the American side. He had the opportunity to present his ideas in front of the "First General Assembly of German Geographers and Hydrographers" in Frankfurt in 1865, and thus to initiate two German polar expeditions of 1868 and 1869/70, which did not bring, however, the success that had been hoped for. During the trip of 1869/70, a young Austrian, 1st lieutenant Julius Payer, had excelled in glacier-trips and expeditions in the interior of the land. He was also instrumental during the discovery of Franz-Josephs-Land later on (Hamann 1993, p. 208–213).

Like Germany, Austria also became enthusiastic about polar expeditions, and two trips were planned, a preliminary one on the Norwegian ship *Isbjörn* (1871) and a subsequent main expedition with the *Tegetthoff* (1872–74). Inspired by Petermann's ideas and realized by the substantial financial backing of count Hans Wilczek, the first expedition was prepared, which was scheduled for the Barents Sea and to Spitzbergen. It showed already the difficulties that were to come, but also provided important results that were necessary for planning the main expedition.

In 1872 an "Association for the promotion of the Austrian North Polar Expedition" was founded in Vienna, supported by the positive attitude of the Academy of Sciences. Influential nobility, ministers and scientists backed the enterprise, and a call for donations was supported by wide circles (headed by far by Graf Wilczek's donation of 52000 fl.) and made the general financing, the construction of the ship and the provision of the outfit of the expedition possible. This second expedition became one of the most spectacular trips to the Arctic with the principal aim to prove the navigability of the European Polar Sea, and to reach East Asia via the polar route (Hamann 1993, p. 16–17).

The expedition's ship *Tegetthoff* had been built in Bremerhaven for this task as a sailing ship of 220 tons with auxiliary steam engine. It was not directly a ship of the k.k. Navy, but the name indicated its association with the Navy, and a major part of the crew and the sea officers had been given leave of absence from the Navy. Commander was ship-of-the-line lieutenant Karl Weyprecht, who had already been commander of the *Isbjörn*. Eventual land explorations should be carried out under the command of 1st lieutenant Julius Payer, an alpinist and cartographer, on leave from the Army (Hamann 1980, p. 75–76).

The expedition trip started in June 1872, the Polar Sea was reached in July, but only five weeks later the ship was caught in pack-ice, and was carried by the current, first north-east, then north-west. In August, land was sighted, but only in November it could be reached on foot by the sailors. It was baptized Kaiser-Franz-Josephs-Land. This was the first major discovery of land at north polar latitudes for 270 years.

The interior of the land was explored in long and tiresome sledge trips, with temperatures of down to $-50°$ C. Under the direction of Julius Payer, a northern latitude of $82°05'$ was reached. The ship was always in danger to be squeezed by the pack-ice, and im May 1874, Weyprecht decided to abandon the ship and to reach the open sea on foot and with boats, which were equipped with sledge skids. Only after

96 days, a trip of 556 km and incredible toils the expedition members reached Novaya Zemlya, and a Russian ship finally brought them to Norway (Hassinger 1950, p. 177–178).

The crew reached Vardö on September 3, and was greeted enthusiastically. News of their salvage quickly spread around the world, and the scientific victory was celebrated as a sort of international enthusiasm. In spite of all problems, neither the "diary of the ship *Admiral Tegetthoff* during the trip from Tromsö to the North Polar Sea" nor Payer's personal diaries, notes of various measurements and observations, as well as his (also artistically valuable) sketches in lead pencil, indian ink, and water-color were lost. Being the first records from such northern latitudes, they could be later used for many comparisons; they cover astronomical, meteorological, cartographical, hydrographical, oceanographical, geographical, geophysical, mineralogical, botanical and zoological areas. Weyprecht, supported by count Wilczek, should be thanked that he proposed his idea of "International Polar Years for the Investigation of the Polar World" on several international scientific meetings and that after his early death his dream of the "First International polar Year" became a reality (Hamann 1993, p. 234).

The trip of the *Tegetthoff* to extreme northern latitudes formed the base for additional exploratory trips, which were, however, carried out in a different way. Eleven countries collaborated and participated in the installation of 14 polar stations. The k.k. Navy sent one of its ships, the *Pola*, to install a polar station on Jan Mayen, which had been assigned to Austria. A large amount of geophysical, meteorological and hydrographical observations was assembled by the scientists, who were taken home after a one-year stay at the station (Hamann 1993, p. 235).

The Academy of Sciences published the scientific results of the two above-mentioned expeditions in its proceedings and memoirs. These publications encountered outstanding scientific recognition, also concerning the peaceful collaboration of different nations (Hamann 1980, p. 77–78).

In 1874/75, the corvette *Erzherzog Friedrich* undertook another circumnavigation of the Earth, to renew and further the political contacts established in 1871/72. Also the scientific observations were important. The mission was lead by ship-of-the-line captain Tobias von Österreicher, and the trip went through the Suez canal, to Singapore, Hongkong, the Malayan Archipelago, San Francisco, along the Chilean coast to the strait of Magellan and Montevideo, and then homeward. On December 8, 1874, a station in Yokohama was used to observe the transit of Venus (Bayer von Bayersburg 1958, p. 66).

In 1874/75, the corvette *Helgoland* was on her way around Africa. The *Nautilus* and the *Aurora* travelled to East Africa in 1874/75. The Suez canal facilitated the trip to East Africa, which was also visited in 1884/85 by the *Frundsberg*, to carry out the nautical training of sea cadets at a wider range, and at the same time to fulfill missions of trade policy. In 1884–86 the *Saida* went to Brazil, Cape Town, Australia and New Zealand, and in 1895–97 a second time to Brazil. Geodetic surveys, soundings, meteorological and tide observations were carried out. The *Fasana* undertook three expeditions in 1889/90, 1891–93 and 1893–95, two of the being circumnavigations of the Earth. Most important tasks were also the nautical training of sea cadets, the technical instruction concerning ship engines, hydrographic surveys and soundings, meteorological and astronomical observations. In 1892/93 Archduke Franz Ferdinand undertook a trip around the world on the cruiser *Kaiserin Elisabeth*. One of his companions was Lorenz Ritter von Liburnau, zoologist of the Museum of Natural History, who initiated extensive collections of ethnographical and scientific objects (Hamann 1980, p. 69–77).

Besides these extensive trips, there was another important task, which had already been planned in 1859, but which had been delayed for quite some time. The charts of the Adriatic sea and its coasts had become outdated, and had to be produced again. About 30 ships of the k.k. Navy participated in this project and sent their reports to the "Adria Commission", founded by the Academy of Sciences for this purpose. The project was not limited to the eastern region of the Adriatic, but the exploration was extended to the adjoining parts of the eastern Mediterranean, even to the Black Sea. The scientific results collected in subsequent years in the fields of geophysics, meteorology and oceanography were published by the Academy of Sciences in five large reports (1869–1880) (Hamann 1980, p. 79–80).

The task of the Navy had gradually changed. In earlier times, military actions and the necessary instruction of the crew were in the forground. Now, it took over more and more scientific, commercial and diplomatic tasks. The Academy of Sciences was actively connected with the Navy Section, and was involved in the commissioning and the travel routes. It had a say in the carrying of scientists and their tasks. The Navy accepted proposals, organized necessary apparatus and stowed them on the ships. It was open to scientific arguments, and many ship-diaries show similarities with scientific reports. Besides this, the training of the crew was still of prime importance, but the

k.k. Navy should be seen abroad as a worthy representative of Austria (Wallisch 1956, p. 172–173).

2. The Corvette Erzherzog Friedrich and the Observation of the Venus Transit of 1874

2.1. Technical Advances and the Construction of the Corvette

In the 19th century, almost all ships of the k.k. Navy were sailing ships, only gradually steam engines were employed. In the beginning, the paddle-wheel, the heavy boiler and the steam engine required much space, and the rigging of the ship was thereby limited. The paddle-wheels were an easy aim for the enemy, and were prone to havary in narrow canals. With strong wind or storm, the wheels submerged into the water in an irregular way, and a constant sailing became impossible.

Only the invention of the screw brought a decisive progress. Its inventor was Joseph Ressel, a forester in the service of the Austrian Navy, who obtained an Austrian patent in 1827. *The screw pleased me most, since I imagined the water being the nut. Only the placement of the screw was not indifferent. Should it drag or pull? In front or on the side, it is subject to the waves, therefore I imagined it between stern post and helm...* wrote Ressel in 1857 about his invention (Aichelburg 1982, p. 44 and 80).

In 1829, the first trial run took place with the screw steamer *Civetta*, built in Trieste. A sea-damage, which had nothing to do with the screw, made the authorities forbid to Ressel further experiments. He had to sell his patent abroad for little money, and the British Navy used his ideas. He remained the little Navy employee, only after his death a monument was erected in front of the Technical Museum (Wallisch 1956, p. 84).

The first Austrian screw steamer *Radetzky* was launched in 1854. It served as a model for the subsequent new ships which for a long time carried the full rigging, since its reduction was not necessary (as would have been the case for paddle-wheel ships). Its advantage was, besides being less prone to damage, that the screw remained under water even in stormy weather, and the steam engine could be used also while sailing (Aichelburg 1982, p. 80–81).

The reinforcement of the ship's wooden sides was done by iron armour plates. Sailing ships, transformed into screw steamers, were in use for a long time, since in the early times steam was only used for entering and leaving the harbour, and during difficult maneuvering.

Travel instructions for captains contained the paragraph *the trip is to be carried out by using sails* (Mayer & Winkler 1991). One should assume that this order should have been followed only in times of favorable wind, but in practice, a commander passed for a good mariner and a promising candidate for a career only when he made the whole trip under sail, and used steam only for entering or leaving the harbour (Mayer & Winkler 1991, p. 95).

We give some numbers for the ship *Erzherzog Friedrich*. She had 1600 tons, a length of 66 metres, a width of 12.20 metres, and was drawing 6 meters. The height of the main mast was 40 metres.

She also was a sailing ship (Fig. 1) with a built-in steam engine of 230 horse-power which propelled a double-winged screw. The ship could reach a speed of 7 nautical miles per hour under favorable conditions and full steam power. The engine was only an auxiliary one which was used as described above. During the trip around the world in 1874–76, the ship was armoured with twelve breech-loader cannons, about half of the amount used during war-time trips (Lehnert 1878, vol. 1, p. 15).

Figure 1. A view of the *Erzherzog Friedrich* on a postcard (ÖSTA, KA, Marine).

2.2. The History of the Erzherzog Friedrich

At the time of the trip around the world, the *Erzherzog Friedrich* counted among the oldest ships of the k.k. Navy. She was a covered corvette, having only one deck (contrary to a frigate, which had two or three decks), a warship with full rigging and three masts. She had been designed by colonel von Jungstedt of the ship construction corps, and was built with high-quality Istrian oak wood. This type of wood had the property to swell, so that leakage caused by cannon balls slowly disappeared (Lehnert 1878, vol. 1, p. 14).

She was launched in 1857 and was generally used for training trips of the Naval Academy, as a coast guard ship, and as a flag-ship. In 1858, the *Erzherzog Friedrich* went to Màroc under the command of Tegetthoff to make inquiries about presumably retained Austrian citizens. In 1864, she was equipped for the North Sea squadron, circumnavigated Spain, but was not used any more in the Sleswig war. In spite of this, she remained stationed in Cuxhaven, together with the *Schwarzenberg*, until early 1866. In the same year, her sides were strengthened with armour plates, and she participated in the battle of Lissa (1866) where she suffered six under-water hits. In 1868, she joined a trip to East Asia together with the *Donau*, and the *Erzherzog Friedrich* was the first Austrian ship that passed, on her way back, the Suez canal. After the trip around the world in 1874–1876, described later, a general overhaul was necessary, which was only finished in 1880, and in 1881 and 1882 major trips to the Atlantic were made. Afterwards, she was mainly used for trips to train young Navy personnel. At the end, she was only used for transports between Trieste and Pola, and was demolished in 1899 (ÖSTA, KA, Khuepach: Schiffskatalog).

2.3. Provisions and Crew of the Erzherzog Friedrich

Provisions for a duration of 90 days could be loaded, but the potable water supply lasted only for four weeks. However, potable water could be made from sea-water with the aid of a distilling apparatus (Lehnert 1878, vol. 1, p. 16). Instead of refrigerators, ice-chests were used, which lasted for three or four days. Freezers needed potable water, either taken from land or using distilled water.

Basic parts of the ship crew's diet were canned or dried food. Canned food was made in Austria, and was mainly stewed steak (Gulash). The two old-fashioned ways of methods of preserving food – drying and salting – provided more types of food: dried vegetables, beans, peas, rusk and salted-down meat. In moderate latitudes and

the dry season, this type of food could be used relatively long. During the rainy season in the tropics, everything started to mould and became inedible, despite storage in tin containers. Fat stock like chicken, muttons, pigs or cattle was on board many ships. The animals often became sick and had to be slaughtered prematurely (Mayer & Winkler 1991, p. 92).

For own usage and for the guests abroad, alcoholic beverages were also available, like wine from the Palugyay & Sons Co. in Bratislava and Szavasi & Comp. in Pest, and liqueurs of the Caligarich Company in Zara. These products were accepted with pleasure abroad, although in the East the competition of Australian wines was high. To investigate the durability and resistance of Austrian products during rapid climate changes during and after the trip, tests of food and beverages was carried out by a commission. (Lehnert 1878, vol. 1, p. 18–19).

The crew was composed as follows: commander Tobias von Österreicher; four ship-of-the-line-lieutenants, among them the author Joseph Lehnert, two midshipmen, eight sea cadets, one ship's surgeon, three machinists, and 232 crew members (Lehnert 1878, vol. 1, p. 15–16).

2.4. Tobias von Österreicher

Tobias von Österreicher was born in Piesling, Moravia, in 1831, as the son of a merchant. In 1848 he entered the Navy as provisional cadet, and retired in 1875. There were no disturbances in his early career. In 1856, his first command was the steamer *Achilles*, 1860/61 the schooner *Möve*, and 1866 the steamer *Elisabeth* and the frigate *Aida*. For his successful participation in the battle of Lissa with the *Elisabeth*, he was decorated with the knight's cross of the Leopold order (ÖSTA, KA, Marine, Qualifikationsliste Tobias von Österreicher, 3927).

In 1865, counter-admiral Freiherr von Wüllerstorff took over the command of the Ministry of Trade. He noted that the existing charts and the knowledge of the Adriatic Sea were outdated. The construction and reconstruction of sailing ships required more detailed nautical information and more exact hydrography. The scale of the existing charts was too small, and noticeable differences between charts and reality existed in the soundings of Venetian waters.

Von Wüllerstorff decided on a long pending coast survey, and invited the Academy of Sciences on December 13, 1866, to investigate the physical conditions of the Adriatic Sea. The Class of Mathematics and Sciences subsequently installed the "Adria-Commission" (Archiv für Seewesen, Vol. 7, issue 12, p. 623–625, 1871).

The commission forwarded a plan for the work (stations around the Adriatic Sea should be installed to carry out magnetic and meteorological observations, measurements of the temperature and density of the sea water, investigations of the tides) to the ministry, which was approved in 1867 by the Ministry of Trade (Meister 1947, p. 96–97).

The financial issue was solved quite rapidly thanks to the willingness of the participating bodies. Only the k.k. Ministry of Education was unable to offer support, so that researches in natural history could not be carried out.

However, the start of the investigations was difficult, since the provision of supplies, the selection of instruments, and the repair of damages of the instruments for the observing stations made a shift to 1868 necessary. The second problem was the question who should carry out the observations: the personnel of the port authorities (apparently that was not a very promising idea), or specialists, recruited to a large extent from teaching staff. Furthermore, observers on board of the ships of the k.k. Navy were necessary (Archiv für Seewesen, Vol. 7, issue 12, p. 623–625).

Also the merchant navy promised to support the observations by their captains, but this action failed completely. At that time, the director of Paris Observatory approached several European governments, among them the Austrian one, asking to pass to him maritime observations. He received a large number of ship's logs from almost all seafaring nations – but not a single meteorological log from the Austrian merchant navy, although the k.k. Central Naval Authority had repeatedly called up to do so (Archiv für Seewesen, Vol. 7, issue 12, p. 623).

Between 1869 and 1874, ship-of-the-line captain Tobias von Österreicher took care of the coast survey in the Adriatic Gulf, and was also presiding the permanent commission for ship construction. In only four months, he succeeded to sound, measure and map the coastline from the mouth of the Po river to that of the Piave river as a "Chart of the lagoons of Venice" in 18 maps, which are a rarity today. He was also asked in 1866 to repeat the charting of the east coast of the Adriatic Sea. The measurements took four years and resulted in a complete charting of the Adriatic East Coast consisting of 167 coast maps, 137 hydrographic maps, and 40 plans of harbours. The particulars of the Royal Italian Navy and this collection of maps formed the basis for the new sea charts and the new sailing handbook (Mayer & Winkler 1991, p. 70–75).

The qualification list of 1871 confirmed that Tobias von Österreicher possessed a high qualification and prudence. During all these years, he was judged to be rather quiet and modest, popular and kept in high esteem, informed in many fields and multi-lingual (he spoke English, French and Italian). Special mention was made of his sense of economy, his knowledge of human nature, his good relations with the ship's crew, and his appreciation for discipline on board and for the good preservation of the ship (ÖSTA, KA, Marine, Qualifikationsliste Tobias von Österreicher, 3927).

3. Erzherzog Friedrich's Trip Around the Earth, 1874–76

Already in March 1874, the Navy Section transmitted the wish to the Hydrographic Authority in Pola that the *Erzherzog Friedrich* be equipped for a scientific mission with all possible opportunities, e.g. for the execution of deep soundings (bathymetry) and for the possible observation of the Venus transit on December 8, 1874 in Yokohama. The envisaged commander Tobias von Österreicher should be contacted and issues concerning instruments and supplies should be discussed with him. It was, however, stated that only available surplus instruments should be provided for the project. Also a travel library should be compiled (ÖSTA, KA, MS/PK, 7/1, No. 313, 1874).

In a letter to the emperor, written April 12, 1874, Navy commander admiral Freiherr von Pöck suggested that the corvette *Erzherzog Friedrich*, who had returned a year before from a trip *that had the purpose to exchange ratifications of the treaties agreed upon with Japan, Siam and China, and to represent the flag in East Asian waters*[2], should be send again on a trip. His opinion was to send again a ship to these waters to avoid too long an intermission, to strengthen the established contacts with foreign countries, and to increase the Austrian reputation. He suggested the *Erzherzog Friedrich*, because the ship's condition and her equipment were good. He estimated a trip of two years. The emperor's agreement to this trip is dated April 16, 1874 (ÖSTA, KA, MS/PK, 7/3, No. 491, 1874).

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[2]ÖSTA, KA, MS/PK, 7/3, No. 4921, 1874.

Already on April 17, von Österreicher obtained the order from the Navy Section *to set sail as soon as possible*[3]. He should take his route as fast as possible (with wind and steam) through the Suez canal and should reach Singapore in mid-July, with as few as possible intermediate stops. The trip should continue through the Chinese Sea to Shanghai, with a short intermission in Hongkong. Special importance was assigned to Shanghai since it was the seat of the k.k. consul general to the courts of Siam, China and Japan. He was reminded to stay not for a long time there since the climatic conditions at this time were the poorest of all the year. Further destinations should be Nagasaki and Yokohama, and then it was left open to his decision to sail to Hakodade, or to await the Venus transit. Also it was left to the discretion of the captain which harbours on the Chinese coast and in the Indian Ocean should be visited, but harbour towns where functionaries entrusted with the office-books of the Austrian-Hungarian consulate had to be visited in any case. The [second] arrival of the *Erzherzog Friedrich* in Singapore should be expected for April, 1875, where also new instructions should be received. Von Österreicher was asked to take care that the stationing of his ship should also be fruitful for science, and, if the available charts would appear to be deficient, to make coast surveys and to carry out soundings. The regions that he would pass would be rich in meteorological phenomena, and would require a collection of accurate and regular data. Only in this way the knowledge of these seas could be increased. The observation of the Venus transit was also suggested, since the special equipment of the ship could contribute to the chain of observing stations (ÖSTA, KA, MS/PK, 7/2, No. 323, 1874).

Thus the Navy Section requested scientific investigations, but the foreseen equipment of the ship was apparently poor, since von Österreicher, in his written answer of April 20, 1874, drew attention to the fact that he would plan to carry out deep soundings (he noted that also the English, the Swedes and Norwegians, as well as the North American coastal ships had made remarkable progress in this field), but that he lacked the necessary equipment, and thus requested its delivery. The application was accepted, however, it was noted that he should look around for equipment in Pola to accelerate the dealings, and should not wait until the last moment (ÖSTA, KA, MS/PK, 7/1, No. 545, 1874).

[3]ÖSTA, KA, MS/PK, 7/2, No. 323, 1874

In his book “Aus fernem Osten und Westen”, von Österreicher noted how necessary his demand for suitable equipment had been, when he described the difficulties he encountered in the region of Borneo island, where he was forced to make soundings almost continuously (for a distance of 1400 nautical miles) because of the presence of coral reefs. He noted that such a coast trip had never been carried out before, at least not with such a big ship, and that the knowledge which was summarized in the British hydrographic maps was extremely defective. He also complained that the old Admirality Charts which were given to him were of absolutely no help (von Österreicher 1879, p. 211–213).

In the meantime, a politically very delicate task had been added. Already in December 1873, the Ministry of Foreign Affairs had written to vice-admiral von Pöck that the k.k. consul general von Overbeck intended to acquire a territory on Borneo, at first as a private person, which would be suitable for the installation of a harbour and later for the installation of a colony. Only at this later time the k.k. Government should deal with taking over this land. Overbeck put forward the wish that a ship should be stationed in these waters to give him protection after his agreement with the American proprietors and the sultan of Brunei.

Vice-admiral von Pöck was asked to hold back the ship *Erzherzog Friedrich* which originally should go to the East-Asian ports via the Americas, to send it eventually through the Suez canal to East Asia (as it was the actual route after all). It was cautiously indicated that the project was not yet ripe and all the legal, maritime and climatic issues had to be examined first, as well as the cost of the acquisition and the foundation and maintenance of a colony, since the authority of the state should not be compromitted in any way. A commission of experts had to examine everything in a strictly confidential way (ÖSTA, KA, MS/PK, 7/2, No. 447, 1873).

Von Pöck appears to have been very much interested in this project, since the Ministry of Foreign Affairs wrote to him on April 14, 1874, that it was pleasing to see that the acquisition of a colony on Borneo, which was also suggested by him, made it necessary to study the situation on location. Only four days later Tobias von Österreicher obtained this order with the note that he had to proceed in a “reserved” way and to write a detailed account for the Ministry of Foreign Affairs (ÖSTA, KA, MS/PK, 7/2, No. 487, 1874).

On May 2, von Österreicher was definitively appointed commander of the corvette *Erzherzog Friedrich* with the order to carry out the

mission in East Asia, and on May 16, 1874 the ship left the harbour of Pola.

Two events, one that was important for astronomy, and the other, that influenced noticeably the career of the commander, will be discussed in detail in the following: the observation of the transit of Venus on December 8, 1874 in Yokohama, and the Dajak-raid on Borneo on June 7, 1875.

4. Venus Transits

Since the earliest times scientists have attempted to determine the distance between Sun and Earth. Already Aristarchos of Samos (around 270 BC) and Hipparchos of Nicaea (around 190–125 BC) have tackled this problem.

Contrary to solar and lunar eclipses, Venus transits are quite rare, they occur about 10–18 times per millenium. Since 1631, seven transits have occurred, in 1631, 1639, 1761, 1769, 1874, 1882, and 2004.

Only after the invention of the telescope and after Johannes Kepler (1571–1630) had established his third law of planetary motions, the problem of the solar distance could be attacked in a novel way. In 1629, Kepler had drawn attention to the Venus transit of 1631, which, however, could not be seen from Europe, and no observations from other places are known. Kepler's third law permitted to derive all distances in the solar system when only one distance is known in absolute units. Venus approaches the Earth at certain times to 1/4 of the solar distance, its parallax is thus four times larger than that of the sun, and relative errors in the measurement should play a minor role. The most suitable moment to measure trigonometrically the parallax of Venus would be during a Venus transit.

The English astronomer Edmond Halley (1656–1742) went one step furher. In his treatise "On the visible lower conjunction...", which appeared in 1681, he proposed how to use such transits: various observers stationed in different parts of the Earth would observe slightly different paths of Venus transiting the solar disk. One had to record precisely the time of ingress and egress of Venus in front of the solar disk by means of a good telescope and a precise clock, and could calculate for the different stations the interesting smallest distances of Venus from the center of the solar disk (Lehnert 1878, p. 599–600).

Halley's method appeared interesting, but is strongly influenced in practice by the "black drop" phenomenon, which does not permit

a precise time determination of the second and third contacts of the transit, and thus degrades the precise determination of the distance. For this reason, the results of 1761 and 1769 were not satisfactory. The black drop effect caused recordings of contact times that differed by as much as 30 seconds for observers at a single station.

The transit of 1769 is connected with two well-known names. On a trip that finally lead to the discovery of Australia, James Cook (1728–1779) should bring the astronomer Charles Greene to a geographically suitable place to observe the transit – Tahiti.

Also Maximilian Hell played a prominent role in the Venus transits. He was appointed director of Vienna University Observatory in 1755, and was in charge of preparing annual ephemerides, a task he began in 1757. The seafaring British and the Berlin Academy started issuing ephemerides only 10 to 20 years later. Hell's ephemerides made him so famous that he was invited by king Christian VII of Denmark to observe the Venus transit of 1769 and the solar eclipse that occurred one day later from the north of Norway, which belonged to the Danish empire at that time. The costs of his expedition were covered by the Danish court, and his calculation of the solar distance, based on his own and other observations, deviates only about 1 percent from the present-day value. However, his results were considered doubtful, and Carl Ludwig von Littrow believed that his handwritten notes were corrected at a later date.

The Venus transit of 1874 should finally bring a breakthrough and yield exact results, since more precise and newly developed instruments and methods were available (e.g. the Fraunhofer heliometer and photography). Modern investigations by Bakhuysen in Leyden and André in Paris had shown in which the black drop disrupts and a thread of light occurs, the geometrical contact takes place.

Governments of many countries and also private persons had organized expeditions to carry out observations from various points of the Earth. England organized 29 expeditions, Germany 5, France 6, Russia 13, the United States of North America 8, Mexico one (to Yokohama), and Austria-Hungary two, one to Yokohama, and the second one to Jassy in Romania (Lehnert 1878, vol. 2, p. 602).

4.1. Observation of the Venus Transit in Yokohama

The Venus transit seems to have been rather a requested routine matter for Tobias von Österreicher, since his first report to the Navy Section was short and pertinent.

He wrote that the transit was observed under good climatic conditions, and no adverse particulars had disturbed the measurements. He promised to provide a more detailed report when the material would have been sorted and studied in detail. He himself had observed with the telescope that was on loan from the Hydrographic Authority. Time had been counted and recorded by midshipman Simon Lehnhardt and cadets Josef Kopetzky and Friedrich Freiherr von John (the large number of people should make the record more secure). A detailed report and 16 solar images, made by the Austrian photographer Baron Stillfried, a resident of Yokohama, were promised at a later time.

Included were the moments of contact, noted by Lehnhardt, which were believed to be exact (in Yokohama mean local time):

Table 1. Von Österreicher's contact timings, first report

1.	First outer contact	11:03:38.8 a.m.
2.	First inner contact	11:29:51.4 a.m.
3.	Second inner contact	03:21:09.50 p.m.
4.	Second outer contact	03:47:55.80 p.m.

On February 3, 1875, the Navy Section transmitted the original report to the Hydrographic Authority in Pola with the instruction to make it available, according to own judgment, to the directors of observatories (ÖSTA, KA, MS/PK, 7/3, I, 1875).

The promised detailed account, sent from Hongkong, arrived on January 27, 1875 at the Imperial War Ministry, Navy Section. At the same time, the accumulated costs were given, and a compensation was requested. Another plea was to arrange a sign of appreciation for the German consul Eduard Zappe, who had offered great hospitality and had given his grounds and his house at their disposal. Furthermore, Zappe had treated well also other Austrian citizens (ÖSTA, KA, MS/PK, 7/3, I, 1875).

The attached detailed report mentioned that von Österreicher had been forced to prepare himself for the Venus transit in Yokohama, due to the necessary repairs of the ship, although the meteorological prospects were infavorable. All other expeditions, except the Mexican one, had therefore decided to install their stations somewhere else. The Austrian station, consisting of a brick pillar and a little wooden

hut with a removable roof had been erected in the garden of the German consul Eduard Zappe. The employed instrument was a 3 1/2 inch dialytic telescope without measuring devices, so that only the moments of contact could be recorded.

The first contact had been predicted for 23:00:42. Somewhat later than expected, a minute reduction of the solar limb could be observed. The first contact was described by von Österreicher as follows:

> About 4–5 minutes before 23 o'clock,... when suddenly a disk of light became visible in the telescope, a little bit larger than later the disk of Venus in the sun. This disk resembled a web of bright rays, bordered by a circular line, which was slightly frayed to the outside of the periphery. Some diametrical rays, like made from strings of pearls, about 12–16, extended from a small inner circle, which had by the way one-eight of the diameter of the total disk of light, to the outer circle, described above, and formed in their totality a delicate apparition of light. The small disk stood near the place where the planet entered the solar disk.
>
> ... The phenomenon suddenly disappeared from my perception, and now – I was eager to observe precisely the ingress – my attention was drawn to a strange undulation, like when one stares in the whirling flames of a furnace, in the solar disk very near below the pointed position... They disappeared when about 1/16th of the diameter of Venus was in front of the solar disk. It is possible that they can be explained by the atmosphere of Venus, as concerns the small disk of light, I like to consider it as a reflex phenomenon, if I am the only observer who has made this observation (von Österreicher 1875, p. 292–293).

During second contact, he was planning to pay special attention to the change of shape of Venus:

> ...taking into account the experiences of previous observations of the Venus transit, I was very much prepared to watch the pear-shaped elongation. It indeed occurred: I saw clearly the spherical shape of Venus and the abovementioned pear-shaped elongation to the side of the contact point...I slowly began to perceive that the disk of Venus had already moved away from the solar disk by a small

> amount, while the above-mentioned elongation had not yet left the solar limb. Only 45.6 seconds after the true contact, the contact of the elongation with the solar periphery ended, and after 10 more seconds, Venus resumed her full circular shape (von Österreicher 1875, p. 293).

He did not make any special observations at third and fourth contact. Since the weather had been favourable during all the time, also the photographic exposures of baron Stillfried could be made, although not to the planned extent, since there was only an improvised darkroom.

Results of the Russian party, lead by the Russian chargé-d'affaires von Struve, and the Mexican expedition, which had worked in the vicinity, were included for comparison, and von Österreicher noted that there were noticeable differences in recorded times (von Österreicher 1875, p. 293–294) (see Table 2).

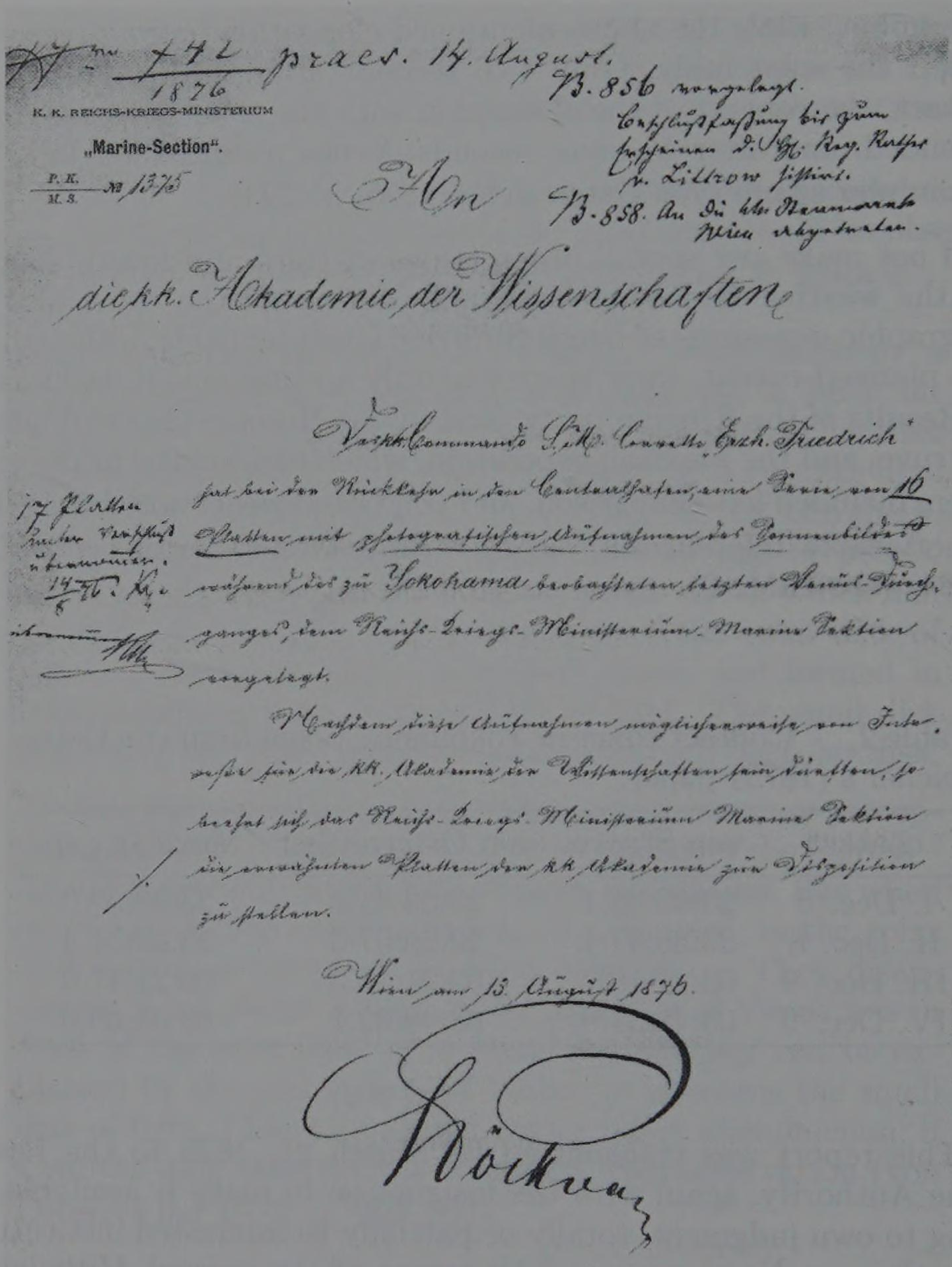
Table 2. Contact times in Yokohama, taken from von Österreicher's (1875) paper.

contact	von Struve	von Österreicher	Mexican exp.
I. Dec. 8	23:03:38.1	23:03:44.5	23:03:59.0
II. Dec. 8	23:30:47.1	23:29:57.3	23:29:51.4
III. Dec. 9	03:21:18.7	03:21:16.3	03:21:47.0
IV. Dec. 9	03:48:31.9	03:48:02.1	03:48:05.0

This report was transmitted on March 21, 1875 to the Hydrographic Authority, again with the instruction to make it available, according to own judgment, totally or partially to interested institutions, and to the own Navy personnel by means of the journal *Mitteilungen auf dem Gebiete des Seewesens* (ÖSTA, KA, MS/PK, 7/3, I, 1875).

A second letter was sent to the k.k. Ministry of Foreign Affairs, asking to express the thanks of the k.k. Government to consul Zappe, based on the report given by Tobias von Österreicher (ÖSTA, KA, MS/PK, 7/3, I, 1875).

On August 13, 1876, the Ministry of War communicated to the Academy of Sciences that the commander of the *Erzherzog Friedrich* upon return from the mission had delivered to the Navy Section a series of 17 plates (von Österreicher had mentioned in his report 16 plates)


Z. 742/1876 praes. 14. August.

K. K. REICHS-KRIEGS-MINISTERIUM

„Marine-Section“.

P. K./M. S. № 1375

Z. 856 vorgelegt. Beschlußfassung bis zum Erscheinen d. Hr. Reg. Rathes v. Littrow sistiert.

Z. 858. An die k.k. Sternwarte Wien abgetreten.

An

die k.k. Akademie der Wissenschaften

17 Platten unter Verschluß übernommen. 14/8 76

Das k.k. Commando S. M. Corvette Erzh. Friedrich hat bei der Rückkehr in den Centralhafen eine Serie von 16 Platten mit photografischen Aufnahmen des Sonnenbildes während des zu Yokohama beobachteten letzten Venus-Durchganges, dem Reichs-Kriegs-Ministerium Marine Section vorgelegt.

Nachdem diese Aufnahmen möglicherweise von Interesse für die k.k. Akademie der Wissenschaften sein dürften, so beehrt sich das Reichs-Kriegs-Ministerium Marine Section die erwähnten Platten der k.k. Akademie zur Disposition zu stellen.

Wien, am 13. August 1876.

Pöckh

Figure 2. Letter of the Imperial War Ministry to the Academy of Sciences of August 13, 1876 (AÖAW, Allgem. Akten, No. 742/1876). Marginalia indicate that a decision was postponed until von Littrow was consulted, and that the plates were transferred to Vienna Observatory.

containing photographic exposures of the sun during the Venus transit, taken in Yokohama. Since it was assumed that these plates would be of interest for the Academy of Sciences, they were put at its disposal (letter of the Imperial War Ministry to the Academy of Sciences, dated Aug. 13, 1876, AÖAW, Allgem. Akten, No. 742/1876). (See Fig. 2).

On October 26, 1876, the Class of Mathematics and Sciences decided that the plates should be given to the director of the k.k. University Observatory. The next day, Carl von Littrow confirmed receipt of the plates (letter of the Class of Mathematics and Sciences to the k.k. University Observatory, AÖAW, Allgem. Akten, No. 742/1876)[4].

It is amazing that Tobias von Österreicher hardly wrote anything about the observation of the Venus transit and also not much more about his other scientific work in his book *Aus fernem Osten und Westen*: he described his trip through East Asia, North- and South America, but even more he sketched landscapes and cities, his invitations and diplomatic missions with various rulers and representatives of different countries, and the life of the natives. A short quotation covers everything that he mentioned in his book about the event:

> The ship remained for a full seven weeks in Yokohama. We have reached this most remote and at the same time most beautiful position in the far East at high speed, and I decided to observe the Venus transit on December 9 here, which made some precautions and preparations necessary. In addition, some necessary ship repairs should be done here, which took a somewhat longer time because of the late season (von Österreicher 1879, p. 92).

Josef Lehnert, who participated as ship-of-the-line lieutenant, also wrote sketches of this trip entitled *Reiseskizzen von der Erdumseglung mit S.M. Korvette* Erzherzog Friedrich *in the years 1874, 1875 and 1876.* He also wrote primarily about his impressions of far countries, however, he mentioned the Venus transit in somewhat more detail, by describing the phenomenon itself and the importance of the observation for the determination of the distance of the sun. He also made it clear that the Austrian observing station, although somewhat improvised, had at its disposal four excellent chronometers of the corvette, but

[4]The plates cannot be recovered at the present time at the Vienna University Observatory (private communication by M.G. Firneis).

besides this only a comet seeker and a 3 1/2 inch dialytic telescope, so that only the four contact times could be determined. He described the search for a suitable place for the observations, which was finally found in the garden of the German consul Zappe, and he described the weather, which he found excellent. He also gave a table of the recorded moments of contact of the three expeditions in the Yokohama area.

In his opinion, it was a major merit of von Österreicher and he should be thanked that Austria was also represented in the Far East. For Lehnert, this Venus transit was only an attempt, because he assumed that the next one of 1882 would yield even better conditions. His final sentence – quoting the astronomer Tobias Mayer – dedicated to these observations runs: *Many generations will feed on this result of brave pursuit of truth, and they will admire the large efforts that were invested by our time, efforts that measure some hundreths of a second.* (Lehnert 1878, p. 602–606).

4.2. The Observation of the Venus Transit of December 8, 1874 in Jassy

Parallel to the observation of the Venus transit in Yokohama during the trip around the world of the corvette *Erzherzog Friedrich*, a trip to Jassy in Romania was carried out by Edmund Weiss, which was funded by the Academy of Sciences.

In the session of the Academy on June 9, 1871, Carl von Littrow put forth a proposal to appoint a permanent commission whose task would be to investigate possibilities to secure a participation of Austria in the observation of the Venus transit in Jassy in 1874. The proposal was accepted, and among others, Carl von Littrow, Edmund Weiss and Theodor Oppolzer were appointed members of the commission. (Protokoll der Sitzung der mathematisch-naturwissenschaftlichen Klasse (minutes of the session of the Class of Mathematics and Sciences), June 9, 1871, AÖAW, Allgem. Akten, B 701).

In the session of June 22, 1871, von Littrow as president of this commission gave a report and presented a draft for a petition to the k.k. Ministry of Cultus and Instruction, in which the Ministry was asked for approval. (Protokoll der Sitzung der mathematisch-naturwissenschaftlichen Klasse (minutes of the session of the Class of Mathematics and Sciences), June 22, 1871, AÖAW, Allgem. Akten, B 703).

On November 19, 1874, Weiss addressed a letter to the Academy of Sciences, pointing out that the Academy had a vivid interest in the participation of Austria in this event, and, as a member of the per-

manent commission, he felt obliged to send again a remainder. Most recent calculations indicated that the zone of visibility was much more to the west than indicated in the first calculations. It would be necessary to overstep the Austrian borders only a little bit to be able to carry out the necessary observations in Jassy. He made the offer to travel to Jassy with his instruments, that would be put at his disposal by the University Observatory, if the Academy would be in a position to offer a travel subsistence of 300 fl. (letter from Weiss to the Academy of Sciences, dated Nov. 19, 1874, AÖAW, Allg. Akten, No. 989/1874).

The Class of Mathematics and Sciences immediately reacted to Weiss' application and asked the plenary session to approve the subsistence of 300 fl., since its opinion was that at this concerted action of all "civilized" nations also Austria had to be present (Petition of the Class of Mathematics and Sciences of November 20, 1874, AÖAW, Allg. Akten, ad No. 909/1874).

This application was approved according to the minutes of the plenary session of November 26, 1874 (Protokoll der Gesamtsitzung (minutes of the plenary session), November 26, 1874, AÖAW, Allgem. Akten, No. 984/1874).

Shortly before, on November 25, 1874, the Academy of Sciences wrote to the Ministry of Finances that Weiss and Oppolzer would travel to Jassy, that the Academy of Sciences supported the project, and that the Ministry was kindly asked to waive the duty on the astronomical instruments carried by the gentlemen upon return at the border customs office of the Lemberg-Czernowitz railway (Letter of the Academy of Sciences to the Ministry of Finance of the Empire, dated November 25, 1874, AÖAW, Allgem. Akten, No. 989/1874).

On the same day, a letter was sent to the Imperial Ministry of Foreign Affairs in which it was pointed out that Austria, like all major civilized nations, should participate in the observations of this important phenomenon. It was requested to contact the Romanian government in this matter and to ask the following favour: waiving duties of the astronomical instruments when passing the border from Bukowina, assistance of the authorities of Jassy in selecting a place to carry out the observations and to erect the instruments. In case of necessity, a list of instruments to be shipped was included (4-inch Fraunhofer telescope, parallactic 4-inch Schäffer telescope, universal instrument, chronometer, and several smaller apparatus) (Letter of the Academy of sciences to the Imperial Ministry of Foreign Affairs, dated Nov. 25, 1874, AÖAW, Allgem. Akten, No. 989/1874).

During the session of the Class of Mathematics and Sciences on December 3, 1874, a letter to the Ministry of Foreign Affairs of the Empire was read, where it was stated that the general consulate in Bukarest had been informed in the desired way, and that it had been asked to become active with the Romanian government (Minutes of the Class of Mathematics and Sciences, dated December 3, 1874, AÖAW, 404/1874).

The observation of the Venus transit was a scientific success, and Littrow reported on it already in the session of the Class of Mathematics and Sciences of December 10, 1874 (Minutes of the Class of Mathematics and Sciences, dated December 10, 1874, AÖAW, 1044/1874).

To conclude, Oppolzer submitted the treatise "Beobachtungen des Venusdurchganges (8. Dezember 1874) in Jassy und Bestimmung der geographischen Breite des Beobachtungsortes", which was written for publication in the Sitzungsberichte [Proceedings] (minutes of the Class of Mathematics and Sciences, dated January 14, 1875, AÖAW, B 808/II /1975).

The southern front garden of the residence of Jassy served as the observing place. The morning of December 8 was not very well suited for the observation of contact times: during egress, it was quite foggy, third contact was well visible, but both the third and the fourth contact took place only 3 degrees above the horizon, and were furthermore influenced by the black drop phenomenon. Oppolzer carried out the determination of longitude and latitude. The difference in longitude was determined by telegraphic comparison of clock readings. Observer Weiss lost Venus at third contact during a strong undulation of the solar limb from the field of view, and saw it again as a little black incision at the solar limb (Firneis 1986, p. 25).

Also from the k.k. consul Hoffmann of Honolulu, a note on results of a British expedition to the Sandwich Islands was transmitted to the Ministry of Foreign Affaris of the Empire, which was passed to the University Observatory (Communication from k.k. consul Hoffmann, AÖAW, B 811/V, 1875).

Already at that time it was felt that a Venus transit was not necessarily the best method to derive the solar parallax. Nevertheless, many countries had put much hope in the results of 1874 (and in those of the next transit of 1882), but the results were plagued with discrepancies and uncertainties. The observations are only of some historical value in the 20th and the 21th centuries.

5. The Raid of Dajak-pirates on the Crew of the Erzherzog Friedrich

If the observation of the Venus transit was a scientific highlight of the trip of the *Erzherzog Friedrich*, there were other events which were less glorious. Without doubt, the most tragical one was the raid of North-Borneo natives, which claimed the lifes of two of the crew of the *Erzherzog Friedrich*, and left two more injured.

Tobias von Österreicher reported the dramatic events in a short note of June 11, 1875 and a more detailed one of June 20, 1875, written in Singapore and addressed to the Imperial War Ministry.

It was calm on the trip to Borneo, the coal supplies had been replenished shortly before. Contrary to the orders, the boilers had to be heated frequently, in order to reach under steam regions of more convenient winds. Progress was hampered by coral reefs and the poor charts at hand. It was decided to approach Borneo near the Siboku river, to chart the region and to carry out soundings, a task that was to be taken over by lieutenant Josef Lehnert, and to prepare a supply of wood (ÖSTA, KA, MS/KA, 4/7, No. 63, 1875).

Already on June 6, 1875, seven boats with natives had been observed, but no importance was attributed to them. On the morning of June 7, 30 crew members with a boat under the command of cadet Nembrini were ordered to land to cut wood; ten of them were carrying weapons. It was rainy and hazy. For a short time, five shadowy canoes with natives were seen from the ship, which was anchoring at a distance of 3 1/2 nautical miles at the mouth of the river. The location where the crew members were working was not visible from the ship, and nothing suspicious was noted. Nembrini assigned all people to the task to cut wood in order to accelerate work, and ordered only one person to watch the boat. At 2 o'clock, five boats approached from the river, and aimed at the working group. Two shots, aimed at the watchman of the boat, were fired. When the others wanted to rescue him and to draw the boat on the shore, they were shot from all sides with arrows and rifles. The watchman jumped into the water and arrived at the shore; others climbed on trees or hid in the bushes. Two sailors were heavily injured, two were killed and the corpses were badly knocked about, all goods on land were stolen, and the boat was taken away. When in the afternoon the steam barcasse returned, which had departed at the same time as the boat with the woodcutters, it was sent to land, to pick up the boat and the crew. Cadet Nembrini gave a report of what had happened. This report was included as an attachment, and included

into the ship's diary. This is the first report (ÖSTA, KA, MS/PK, 4/7, No. 63, 1875).

In the second report, to which a report of the raid, written by cadet Nembrini, as well as a report on the dead and injured persons was attached, Nembrini was lauded, except that he should not have assigned the whole crew to the wood-cutting. His instruction had been to use five persons as posts, and to have one watchman for the boat.

Seven persons received a laudable recognition on board, and the small medal of bravery was applied for in the report. On June 9, crosses were erected for the two fallen sailors, whose corpses could not be recovered.

The newspapers learned about this event, and the *Neue Presse* of July 22, 1875, published an article entitled "Austria in a battle with pirates", and referred to the report of a correspondent on board the *Erzherzog Friedrich*, and to an article which had appeared in the *Triester Zeitung*, and initiated by a private letter. The *Neue Presse* raised massive reproaches and accused the captain to have been too negligent. The region was known as a hiding-place of pirates, the corvette had anchored too far away, the number of rifles had been too small, and the sighing of the boats the day before should have necessitated a securing of the working group. One should almost be happy that not all sailors had been killed. One would expect an official report, in order to hopefully publish a more favorable judgment (Neue Presse, July 22, 1875).

On August 8, 1875, a letter was sent from the Imperial military chancellor to Tobias von Österreicher, in which he was reproached to not have made the precautionary measures which were demanded by the circumstances. The following things were criticized: He should have given the command to an officer, and not to a young cadet, since the working crew could not be seen from the ship; the complete crew should have been armed, since it was known that this was a dwelling place of half-wild and martial natives; since natives in ships had already been seen, one should have been careful and protective measures should have been taken. In addition, a reprimand was expressed, since reports (original reports in several daily newspapers) had reached the public obviously through persons belonging to the crew of the *Erzherzog Friedrich*, and such a tactless incident could bring a negative influence to the military service. The letter concludes with a request to give an immediate order referring to this to the complete crew (ÖSTA, KA, MS/PK, 7/7, No. 1072, 1875).

On October 23, 1875, von Österreicher addressed a letter to the *Triester Zeitung* which was published in the issue of November 20, 1875. He rejected the peculiar and hateful article, and, since a detailed official report was obviously not forwarded to the newspaper, he assumed that it was his duty to reject all fictive and wrong accusations. It was mainly his task to explain that the martial character of the natives had not been known before, that his crew had not climbed trees, since there were no trees, and that also the claim that the captured boat with the pirates had been seen from the ship was not true (Triester Zeitung of November 20, 1875).

Von Österreicher had not discussed his procedure with the Navy Section beforehand, but only in a letter of October 24, he put forward the reasons for his action. Since there had been no official reply to the newspaper articles, this had let him, in his position as a ship commander, to initiate an official correction. He found it inconceivable that his two reports had not been published by the Imperial War Ministry, Navy Section, and thus rumors and prejudices for his ship had arisen. As a confirmation of his complaint, he included a rectification of his corps of officers (who had all signed) to the press note of July 22, 1875 (ÖSTA, KA, MS/PK, 7/7, No. 83, 1875).

The Imperial War Ministry, Navy Section, responded on November 26, 1875, that a reply to the newspaper had not deemed to be necessary. The report had corresponded to a large extent to reality, and a reply would have made the incident appear in no better light. The correction instigated by the captain was disapproved, since this was not permitted by the service regulation, and was therefore termed a punishable unauthorized action. In addition, attention was drawn to absurdities in the report (climbing on trees – there were no trees, boat was taken away – the boat was not seen to be taken away), and he was asked for a correction.

At the same time, a reproach was issued, and von Österreicher's complaint was rejected. It had been presented in an inappropriate way, and was not sufficient. It disapproved the procedure of the authority, and he had not shown "the necessary military subordination." (ÖSTA, KA, MS/PK, 7/7, No. 1851, 1875.) The War Ministry, Navy Section, assumed it to be its duty to "oppose with strictness such a punishable behaviour" (ibid.). The section refrained from an immediate discharge, which was provided for in such cases, in order not to damage even more the reputation of the Navy.

Von Österreicher was reminded not to provoke another reason for discontent, and he was informed that after the end of his mission, additional steps for his punishment would be initiated (ibid.).

In his book *Aus fernem Osten und Westen* Tobias von Österreicher described this raid in much detail, although otherwise he did not deal with details of his work. Obviously he intended to justify himself in this way.

He described the little chances of his crew fighting against the natives, who had a strong shield made from thick planks which could be put up, and was equipped with a bullet-hole. Two sailors who recognized this device tried, hidden behind rocks, to aim at the canoes from the side, and they were successful, since natives were hit, among them the suspected chief. Another arriving canoe forced them to leave the hiding-spot and to escape.

He mentioned that the raiders had been no Dajaks, but rather Malayans of the Sulu-group, which were known to be very cruel and to mount their rifles in the canoes. He assured that in the evening after the incident, the region had been searched carefully, without finding something suspicious or a settlement. Since the coral barrier had been followed to the end, it had been necessary to turn and to continue the trip (von Österreicher 1879, p. 227–230).

The harbour place where the *Erzherzog Friedrich* had anchored as the first European ship, and the two reefs through which the corvette had sailed were named after the ship, the charted mountains were named "Andrassy", "Wüllerstorff" and "Pöck" to honour those which had contributed most to make this expedition a reality (von Österreicher 1879, p. 230).

The intention to found a colony on Borneo, for which purpose von Österreicher should have made investigations appears to have come to nothing. Von Österreicher mentions a meeting with von Overbeck in Hongkong, to discuss the matter with him, and to gain an overview. After this discussion he stated that in his opinion the purchase of a valuable object was difficult because of the unclear propriety situation, the interference of major powers, and the usual corruption, and it would be very tiresome to install a colony, even when the purchase of land had been carried out (ÖSTA, KA, MS/PK, 7/2, No. 1349, 1875).

After these impressions and certainly also in view of the raid on the *Erzherzog Friedrich* crew, the purchase of land was not pursued any longer and the ship was called home.

The qualification list of Tobias von Österreicher, issued in 1875 after the Dajak-raid, contains in the judgment row "behaviour on duty" for the first time a reproach: "it is in general appropriate, but full of self-love and a major presumption, during the course of the year, he took the liberty to use a very arrogant language in an official letter to the Navy" (ÖSTA, KA, Marine, Qualifikationsliste Tobias von Österreicher, 3927). In "Notes" it is mentioned: "He has fulfilled his mission well, except the event at the mouth of the Siboku river on Borneo. During this event, he has shown little foresight concerning the security of the own crew, and by this behaviour alone the known unfortunate outcome to the disadvantage of the Navy" (ibid.).

After the end of the mission, von Österreicher was assigned to the port authority in Pola, and since October 16, 1876 to the Navy Section.

The Borneo incident strongly influenced his further career, since in each qualification list after 1875 it was stated that the qualification for a promotion was not given, since he showed, although being a suitable sailor, a lack of disposition and prudence. He was always described as diligent and well educated, but he never got rid of the reproach of self-love and a major presumption until his retirement. In addition, he was rebuked since he ignored the existing orders, and provoked admonitions, but it was noted, that he had become calmer, polite and well available.

Upon retirement he was promoted counter-admiral. Von Österreicher died in Vienna on August 27, 1893 (ÖSTA, KA, Marine, Qualifikationsliste Tobias von Österreicher, 3927.).

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Beobachtung des Venusdurchganges

Linienschiffs-Capitain Tobias Freiherr v. Oesterreicher, Commandant S. M. Corvette FRIEDRICH.

Einem Berichte des Linienschiffs-Capitain Tobias Frh. v. Oesterreicher über die gemachte Beobachtung des Venusdurchganges entnehmen wir im Auszuge nachfolgenden interessanten Theil:

Die Verhältnisse der Kreuzung und die an dem Schiffe nothwendigen Herstellungsarbeiten liessen mir bezüglich des Ortes zur Beobachtung des Venusdurchganges keine Wahl und ich beschloss daher mich in Yokohama auf diese Beobachtung vorzubereiten, obgleich eingeholte Erkundigungen über die meteorologischen Verhältnisse des Ortes wenig Hoffnung gaben, dass das Wetter meinem Vorhaben günstig sein werde. Yokohama wurde von allen grösseren europäischen Expeditionen gemieden und nur die mexikanische Expedition, bestehend aus drei Herren, langte in der zweiten Hälfte des November daselbst an und richtete sich ein Observatorium ein.

Bezüglich meines eigenen Observatoriums entschied ich mich nach zweitägigem Suchen, wobei mir auch von Seite Sir Harry Parkes, ferner des italienischen Consuls Bruni und des Geschäftsträgers für Russland von Struve die freundlichsten Anerbietungen gemacht wurden, dasselbe im Garten des k. deutschen Consuls Herrn Eduard Zappe zu errichten, da mir neben der liebenswürdigen und zuvorkommenden Aufnahme von Seite des Consuls, dieser Platz alle Bedingungen zu einer ruhigen Beobachtung zu bieten schien. Nachdem ich mir die Ueberzeugung verschafft hatte, dass die benachbarten Bäume in keiner Weise die Beobachtungen hindern werden, wurde zum Baue eines gemauerten Pfeilers und einer kleinen Bretterhütte mit verschiebbarem Dache geschritten.

Mein Beobachtungsort lag so nahe an dem von Fleuriais im Jahre 1873 bestimmten astronomischen Punkte, dass eine geodätische Uebertragung leicht ausführbar war. Dieselbe ergab für die Lage meines Observationspfeilers:

$139^0\ 40'\ \ 0''$ O. L. v. Greenwich,
$35\ \ 26\ \ 59$ N. B.,

wobei die Lage des astronomischen Punktes von Fleuriais zu

$139^0\ 40'\ 28''$ O. L. v. Greenwich,
$35\ \ 26\ \ 49$ N. B.

angenommen ist. Auf eine eigene Ortsbestimmung verzichtete ich deshalb, weil ich mit den mir zu Gebote stehenden Mitteln nicht hoffen konnte, ein besseres Resultat zu erhalten.

An Instrumenten hatte ich nur ein $3^1/_2$zölliges dyalitisches Fernrohr, welches keinerlei Messapparate besass, und konnte daher blos die vier Contactmomente beobachten.

In den ersten Tagen des December wurde das Fernrohr montirt und mit demselben die Sonnenscheibe beobachtet, wobei das passendste Ocular und das geeignetste Sonnenglas ausgesucht wurde. Bei der Beobachtung sollten das Regel-Chronometer, ein Sternzeit-Chronometer und ein Taschen-Chronometer benützt werden. Ersteres übernahm Linienschiffs-Fähnrich Simon Lehnhardt, welcher auch die geodätische Aufnahme des Beobachtungspunktes ausgeführt hatte, die beiden anderen wurden durch die Seecadeten Josef Kopetzky und Friedrich Freiherr v. John besorgt.

Der Morgen des 9. December brach mit heiterem, klarem Himmel an, und der Zustand der Atmosphäre versprach die günstigste Witterung für diesen

Figure 3. A reproduction of Tobias von Österreicher's article that appeared in the *Mitteilungen auf dem Gebiete des Seewesens*.

Tag. Um $10^3/_4$ Uhr Vormittags waren bereits alle Beobachter an ihrem Posten und mit Spannung wurde der Eintritt des Phänomens erwartet, der nach den Angaben des „*Nautical Almanac*“ zu Yokohama am 8. um $23^h\ 0^m\ 42^s$ stattfinden sollte; doch verstrich die erste und zweite Minute nach 23^h und auch die Hälfte der dritten Minute, ehe ich, etwas tiefer als die Angabe des „*Nautical Almanac*“ lautet, auf circa 60° statt 64° vom Vertex die Verringerung der Peripherie des Sonnenrandes um die Breite eines Haares bemerkte. Nach etwa 8 — 10 Secunden und nachdem ich mir die Gewissheit hierüber durch sorgfältigen Vergleich mit dem ober- und unterhalb befindlichen Sonnenrande verschafft hatte, liess ich die Zeit notiren.

Diese Notirung gab für den ersten Contact:

Regel-Chronometer	13^h	45^m	$4{\cdot}0^s$	mittlere Greenwicher Zeit,
Taschen- „	—	—	4·3	
Sternzeit- „	—	—	5·3	
Mittel	13^h	45^m	$4{\cdot}5^s$	mittlere Greenwicher Zeit,
	23	3	44·5	„ Yokohama „

und unter der Annahme von $9{\cdot}0^s$ Verspätung in der Notirung

	13^h	44^m	55·5	mittl. Greenwicher Zeit,
	23	3	35·5	„ Yokohama „

Für den zweiten Contact wurde notirt:

Regel-Chronometer	14^h	11^m	$17{\cdot}1^s$	mittl. Greenwicher Zeit,
Taschen- „	—	—	17·4	
Sternzeit- „	—	—	17·3	
Mittel	14^h	11^m	$17{\cdot}3^s$	mittl. Greenwicher Zeit,
oder	23	29	57·3	„ Yokohama „

Für den dritten Contact wurde notirt:

Regel-Chronometer	18^h	2^m	$35{\cdot}3^s$	mittl. Greenwicher Zeit,
Taschen- „	—	—	37·0	
Sternzeit- „	—	—	36·5	
Mittel	18^h	2^m	$36{\cdot}3^s$	mittl. Greenwicher Zeit,
oder	3	21	16·3	„ Yokohama „

Für den vierten Contact wurde notirt:

Regel-Chronometer	18^h	29^m	$21{\cdot}6^s$	mittl. Greenwicher Zeit,
Taschen- „	—	—	22·2	
Sternzeit- „	—	—	22·6	
Mittel	18^h	29^m	$22{\cdot}1^s$	mittl. Greenwicher Zeit,
oder	3	48	2·1	„ Yokohama „

Nachdem die Resultate hier aufgezählt sind, sei es gestattet, über die einzelnen Phasen dieser beobachteten Contactmomente die folgenden Bemerkungen anzureihen.

Erster Contact.

Ich stand am Teleskope und erwartete mit Aufmerksamkeit den Beginn, als ganz unvermuthet eine merkwürdige Erscheinung auftrat. Es fehlten beiläufig 4—5 Minuten auf 23^h — die Stunde, welche der „*Nautical Almanac*“ für den Beginn angibt — als plötzlich ein Lichtscheibchen, um ein geringeres grösser als später die Venus in der Sonne, im Teleskope sichtbar wurde. Dieses Scheibchen glich einem Gewebe von hellen Strahlen, von einer Kreislinie eingefasst, die jedoch nach der Aussenseite der Peripherie leicht gefasert war. Einzelne diametrale Strahlen, wie aus Perlenschnüren, etwa 12—16, liefen von

Figure 3. Continued: reproduction of Tobias von Österreicher's article from the *Mitteilungen auf dem Gebiete des Seewesens.*

einem kleinen inneren Kreise, der beiläufig ein Achtel des Diameters des ganzen Lichtscheibchens hatte, zu dem äusseren, früher beschriebenen Kreise hin und bildeten zusammen eine zarte Lichterscheinung. Das Scheibchen stand nahe der Stelle, wo der Planet in die Sonnenscheibe eintrat; es folgte aber leichten Bewegungen des Teleskopes. Ich schloss für Momente das Auge, um es ausruhen zu lassen, sobald ich aber wieder in das Teleskop blickte, war das Lichtscheibchen abermals zu sehen. Das Phänomen verschwand plötzlich meiner Wahrnehmung und nunmehr wurde ich — immer gespannt den Eintritt genau zu beobachten — auf ein sonderbares Wallen, etwa wie wenn man die Flammenwirbel eines Hochofens anblickt, in der Sonnenscheibe ganz nahe unterhalb des pointirten Punktes aufmerksam. Der Rand der Sonne war bis dahin immer ganz ruhig und gleichmässig erschienen, auch nicht die geringste Bewegung an demselben war während der früheren Beobachtungen bemerklich gewesen. Diese Wallungen erstreckten sich auf die doppelte Länge und auf die halbe Breite jenes Durchmessers, mit welchem Venus später als dunkle Scheibe im Fernrohr sich präsentirte, und in dem Masse, als Venus in die Sonnenscheibe vorrückte, nahm auch die Breite dieser Wallungen zu. Sie waren zu Ende, sobald etwa $^1/_{16}$ Durchmesser der Venus in die Sonnenscheibe eingetreten war. Dieselben könnten ihre Erklärung in der Venusatmosphäre finden, das Lichtscheibchen aber möchte ich als eine Reflexerscheinung betrachten, wenn ich der einzige Beobachter bin, der diese Wahrnehmung gemacht hat. Nebenbei bemerke ich, dass ich mit voller Ruhe beobachtete.

Unerwähnt möge es nicht bleiben, dass in dem Masse, als der zweite Contact herankam, auf dem sichtbaren Theile der Venus ein feines maschenartiges Lichtgeäder von unregelmässigen Polygonformen deutlich sichtbar war, aber alsbald verschwand, sobald Venus voll in der Sonnenscheibe stand, wo sie sich als dunkle Scheibe darstellte.

Zweiter Contact.

Als der zweite — erste innere — Contact herankam, sah ich deutlich die sphärische Gestalt der Venus vor der Sonnenscheibe. Mit Rücksicht auf die Erfahrungen früherer Beobachtungen des Venusdurchganges war ich sehr auf der Huth bezüglich der birnförmigen Verlängerung. Dieselbe trat auch hier ein; ich sah deutlich den kugelförmigen Körper der Venus und die erwähnte birnförmige Verlängerung nach der Seite der Contactstelle. Ich verfolgte daher fortwährend an der Rundung des Planetenkörpers die kreisförmige Fortsetzung bis zum Contactpunkte.

Zuerst liess ich den Zeitpunkt notiren, als noch eine dünne Sichel der Venus sich ausserhalb der Sonne befand, sodann als noch ein Pünktchen über dieselbe hinausragte und endlich als ich die Kreisform des Venuskörpers im innern Contact mit dem Sonnenrande erblickte. Zu dieser Zeit betrug jedoch die Berührung der birnförmigen Verlängerung mit dem Sonnenrande noch gut $^2/_3$ des Venusdurchmessers. Diesen Moment halte ich für die richtige Zeit des ersten inneren Contactes, da ich mit Genauigkeit die eben erwähnte Verlängerung von der Peripherie des Planeten unterschied. Ich nahm allmälig wahr, dass die Venusscheibe sich bereits um eine kleine Grösse vom Sonnenrande entfernt hatte, ohne dass die besagte Verlängerung den Sonnenrand verlassen hätte. Erst 45·6 Secunden nach dem wahren Contacte hörte die Berührung der Verlängerung mit der Sonnenperipherie auf, und nach weiteren 10 Secunden nahm die Venus die volle kreisrunde Form an.

Ein Perlen des an der Ostseite durchbrechenden Sonnenlichtes habe ich nicht wahrgenommen.

Figure 3. Continued: reproduction of Tobias von Österreicher's article from the *Mitteilungen auf dem Gebiete des Seewesens.*

Dritter und vierter Contact.

Beim dritten und vierten Contacte wurden keine besonderen Wahrnehmungen gemacht.

Entgegen jeder Erwartung fand keine scheinbare Verlängerung der Venusscheibe statt und man konnte beim dritten Contact genau die Zeit der beiden Scheibenberührungen beobachten. Ich liess zwei Momente notiren, die um 20·7 Secunden differiren; bei dem ersten war noch ein ganz dünner Lichtfaden an der Westseite der Venus bemerkbar, beim zweiten war der Contact bereits eingetreten, aber nach oben und unten waren die Lichthörner wahrnehmbar.

Den vierten Contact notirte ich zweimal; einmal als noch ein Punkt in der Sonnenscheibe stand, das zweitemal als noch eine Haaresbreite fehlte, um den Sonnenrand zur vollen Rundung zu ergänzen. Aehnlich wie bei der Eintrittsbeobachtung und circa 10 Secunden bevor das Phänomen endete, bemerkte ich abermals ein Wallen in der dem Austritte nächst gelegenen Partie des Sonnenrandes, jedoch in viel schwächerem Masse als beim Eintritt.

Kein Wölkchen hatte im Laufe des Tages den Himmel getrübt und die Station war gegen alle Erwartung eine der begünstigtesten in Ostasien. Am letzten Tage hatte sich der in Yokohama als Photograph etablirte Baron Stillfried angeboten, photographische Aufnahmen zu machen und sein freundliches Anerbieten wurde angenommen.

Die Aufnahmen sollten von 15 zu 15 Minuten stattfinden, doch liess sich diese Zwischenzeit nicht gleichmässig einhalten, da die Dunkelkammer blos improvisirt worden war.

Baron Stillfried wendete Momentphotographie an und die notirten Zeiten sind bis auf Zeitsecunden genau. Die 16 Platten wurden mir mit in dem Glase eingeritzten Nummern überlassen und werden seinerzeit nach Wien gesendet werden.

In Yokohama beobachtete auch der russische Geschäftsträger von Struve, Bruder des russischen Astronomen und selbst auch vielfach astronomisch thätig. Er hatte ein um ½ Zoll kleineres Teleskop als ich, seine Chronometer waren ganz vorzüglich verlässlich und sein Standort etwa eine Breitenminute südlich und eine Längenminute westlich von dem meinigen entfernt.

Wie erwähnt, hatte sich auch die mexikanische Expedition in Yokohama eingefunden und ihren Standort 20 Bogensecunden nördlich und 30 Bogensecunden westlich von dem meinigen gewählt. Mit Herrn von Struve tauschte ich persönlich die Beobachtungszeiten aus. Einer der drei mexikanischen Astronomen war so freundlich, dem Linienschiffs-Fähnrich Lehnhardt seine Beobachtungszeiten mitzutheilen, die ich hier anführe mit der Bemerkung, dass die Zeitnotirungen der zwei anderen Herren erheblich von diesen Notirungen differiren sollen.

Im Nachfolgenden sind die Beobachtungen nebeneinander (mittlere Zeit von Yokohama) angeführt.

Contact.	von Struve.	Oesterreicher.	Mexikan. Astronom.
I.	$23^h\ 3^m\ 38{\cdot}1^s$	$23^h\ 3^m\ 44{\cdot}5^s$ mit einer wahrscheinl. Verspätung von $-9{\cdot}0^s$	$23^h\ 3^m\ 59{\cdot}0^s$
II.	23 30 47·1	23 29 57·3	23 29 51·4
III.	3 21 18·7	3 21 16·3	3 21 47·0
IV.	3 48 31·9	3 48 2·1 mit einer wahrscheinl. Verfrühung von $+9{\cdot}0^s$	3 48 5·0

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Figure 3. Continued: reproduction of Tobias von Österreicher's article from the *Mitteilungen auf dem Gebiete des Seewesens.*

ASTRONOMICAL HERITAGES: Astronomical Archives and Historic Transits of Venus
Journal of Astronomical Data, Vol. 10, 7, 2004
Christiaan Sterken, Hilmar W. Duerbeck, eds.

A Remarkable Series of Plates of the 1882 Transit of Venus

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Abstract

We discuss a series of photographic plates of the 1882 transit of Venus, taken by David P. Todd at Lick Observatory. These plates are by far the most complete photographic record of the transit and have been lying dormant in the Lick archive for 120 years. The plates also have a place of importance in the history of photography.

1. Construction of Lick Observatory

Construction of Lick Observatory on Mount Hamilton in the Diablo Range east of San Jose, California, began in earnest in the summer of 1880 with the removal, by hand, of 70,000 tons of rock to clear a level platform for the observatory buildings. Years had been lost to legal entanglements since the ailing, eccentric James Lick had first promised a portion of his fortune for the construction of the observatory, but by 1881 the first instruments – a 12-inch Clark equatorial and a 4.1-inch Fauth transit telescope – had been installed on the mountaintop. Adjoining the transit house, a 40-foot Clark photoheliograph was also taking shape.

Though the casting of the glass for its lenses delayed completion of the observatory's centerpiece – the great 36-inch equatorial – for another five years, scientific work was begun on the mountain with the smaller instruments. With the important transit of Venus approaching

Figure 1. David Peck Todd (no date). Photo courtesy of *The Mary Lea Shane Archive* of the Lick Observatory.

and no formal scientific staff yet appointed, Captain Richard S. Floyd, president of the Lick Trustees, tried to persuade Simon Newcomb – dean of American astronomers and an advisor to the Lick Trust – to observe the transit from Mount Hamilton. When Newcomb opted for a better view from South Africa, Floyd invited young David P. Todd (Fig. 1), newly appointed professor of astronomy at Amherst College, to direct observations from Mount Hamilton. Todd accepted with alacrity. In addition to the 12-inch and 4.1-inch telescopes, Todd would have at his disposal the 40-foot photoheliograph, an instrument ideally suited to the observations.

2. David P. Todd's Expedition

Though Todd's expedition was not one of the eight outfitted that year by the United States Transit of Venus Commission, it may be regarded as a ninth, unofficial one. Before coming to Mount Hamilton, Todd and his assistant J. L. Lovell visited Washington, D.C., where they received special instructions for photographic work from U. S. Naval Observatory astronomer William Harkness, at whose urging the Commission's 1882 expeditions had been mounted. Lick's Clark photoheliograph was nearly identical to the eight constructed by the same maker for the Commission expeditions, and Harkness surely briefed Todd and Lovell in the techniques that would make their observations compatible with those of the other parties.

Like its Commission cousins, the Lick instrument was a horizontal telescope consisting of a 7-inch heliostat mirror and 5-inch objective of 40-foot focal length (see Figs. 2 and 3 for the photoheliograph house, and Fig. 4 for the site plan of Lick Observatory). Mirror, lens, and a photographic plate holder were mounted on piers, the last inside a light-tight photographic building. A long tube enclosed the path between objective and focal plane.

Todd and Lovell arrived on Mount Hamilton with just over two weeks to prepare for the transit. Todd regarded the photographic observations as of primary importance, and brought his considerable gifts as mechanical engineer to bear on the new photoheliograph, bringing it to completion with various modifications and making a painstaking determination of its photographic focus. His work was aided by a long run of fine weather, unusual for that time of year on Mount Hamilton. Figure 5 shows the house of the photoheliograph and the dome of the 36-inch refractor in a later photograph.

The sun rose into a clear sky at 7 a.m. on the day of the transit. Exposures began about a quarter of an hour after sunrise with Venus

Figure 2. The photographic house of the photoheliograph is the small building with the vaulted roof just left of center in this view looking northeast (no date, but before 1907). Photo courtesy Darrell Severinsen, Lick Observatory.

Figure 3. The photographic house of the photoheliograph is at center, with its horizontal tube extending north toward the heliostat. Dome of the 36-inch refractor is in the background. View is looking southwest (no date, but between 1888 and 1907). Photo courtesy Darrell Severinsen, Lick Observatory.

already well advanced on the sun's disk. The first dozen plates were underexposed due to the considerable extinction near the horizon, and the sun's disk was distorted by atmospheric refraction. But as the sun gained altitude image quality rapidly improved, and another 135 wet-process plates, most of excellent quality, were exposed over the next 3 hours and 48 minutes. Figure 6 shows some sample images.

Captain Floyd, in the meantime, followed the progress of the transit using the 12-inch equatorial, making several drawings and observing the third and fourth contacts. As the end of the transit neared, Todd left the photoheliograph to visually observe the two contacts with the transit telescope. Photographic observations were suspended soon after third contact.

The importance accorded the photographic observations is borne out by the great care taken to record the times of exposures: an electric chronograph, triggered by the photographic shutter, recorded the

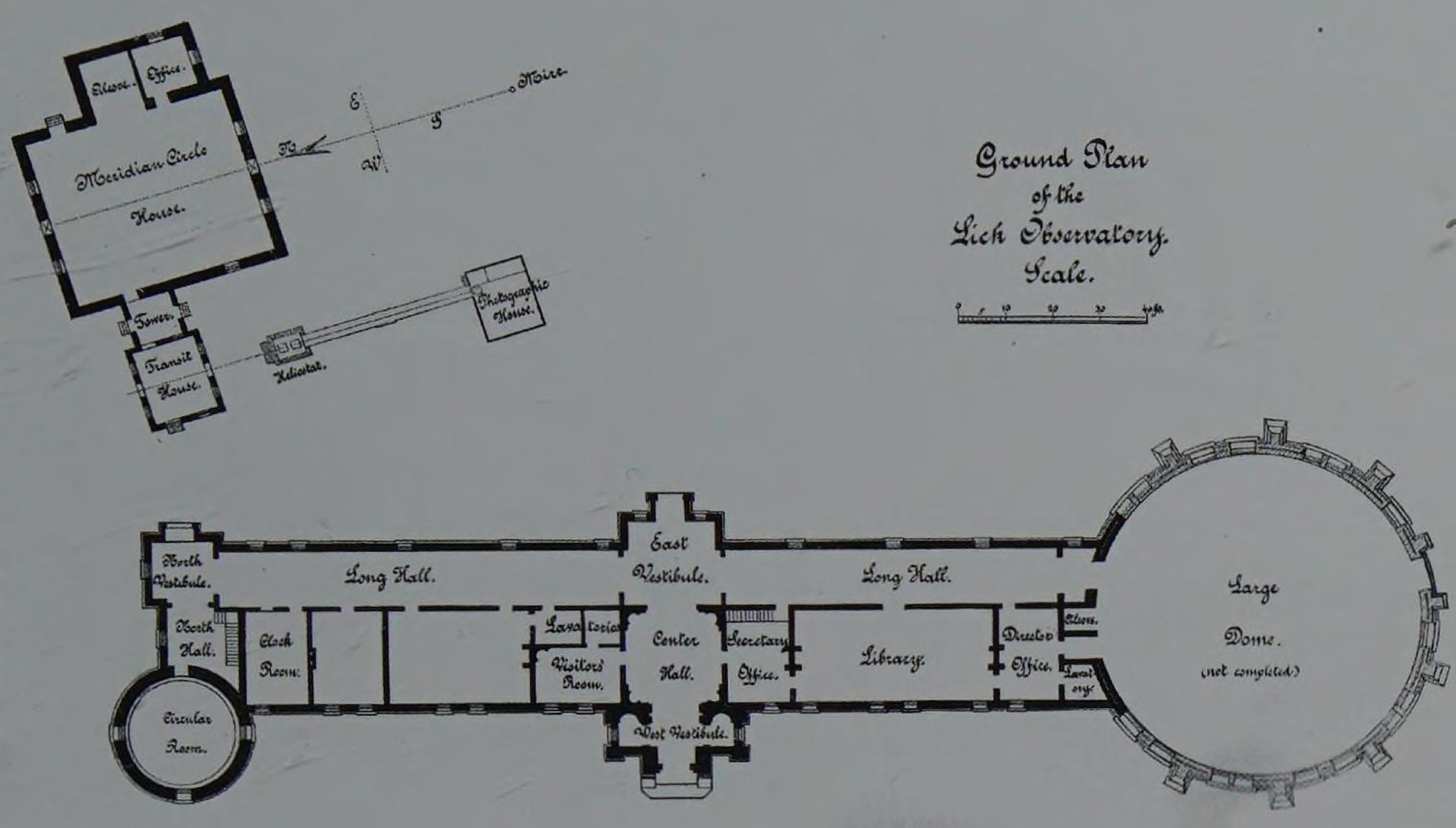

Figure 4. The site plan of Lick Observatory, showing the location of the photoheliograph (Photographic House and Heliostat). From *Publications of the Lick Observatory*, Vol. I, Sacramento, 1887.

times automatically. Todd kept a second record by hand, and Mrs. Cora Floyd and Mrs. Fraser, the wife of the observatory superintendent, made yet another record by listening to the clicks of the chronograph armature from their station in the transit house. But despite the doubly redundant timekeeping, we could find no record, in print or otherwise, of the times of the individual exposures. So much for the durability of the scientific record!

3. The Photoheliograph Plates

The 147 plates taken with the photoheliograph were left in the observatory plate vault on Mount Hamilton. To ensure the safety of the data, two complete copies were made and deposited with the Lick Trust in San Francisco and at Amherst College, respectively. Only the original negatives appear to have survived, largely undisturbed for more than a century, until 142 were relocated by the authors in the Lick plate archive.

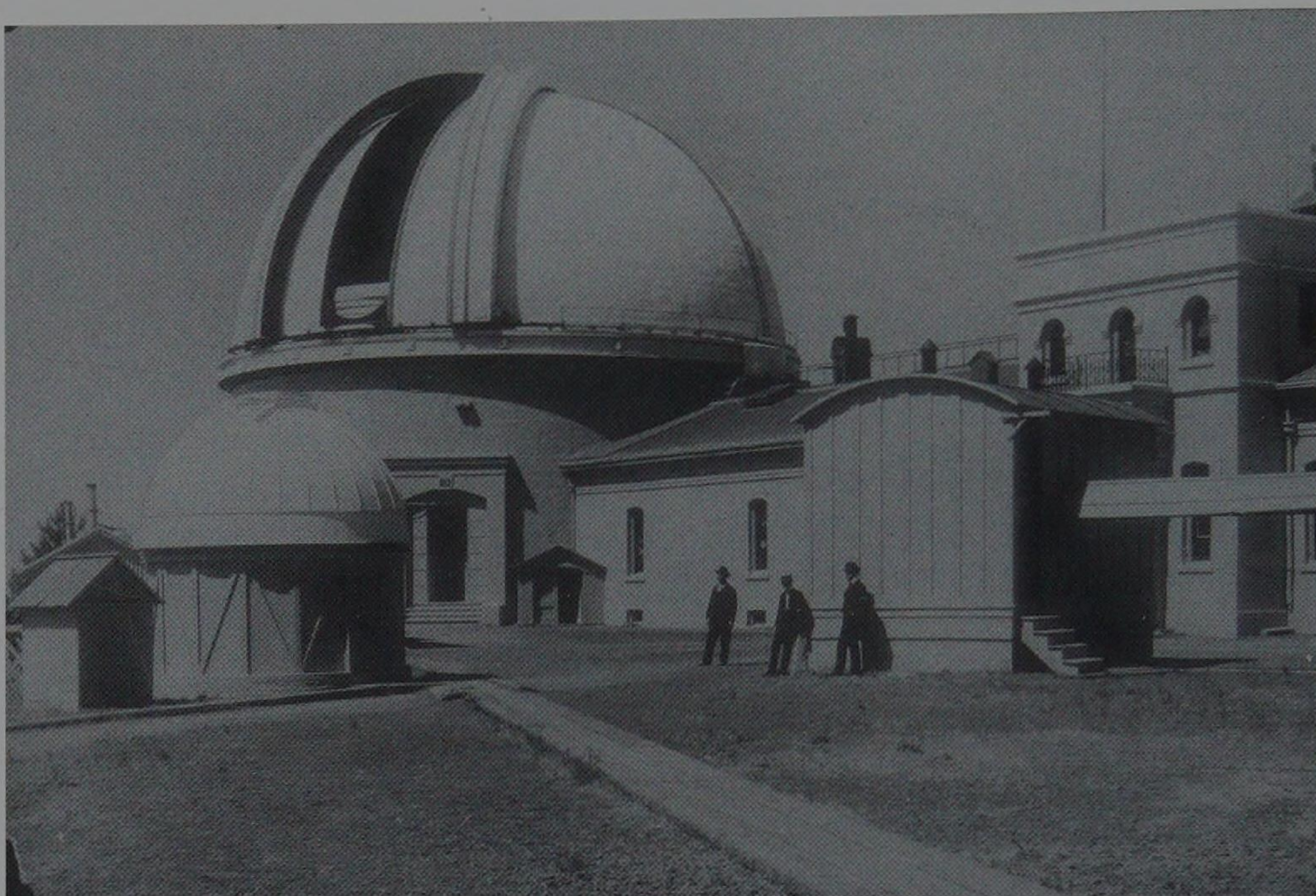

Figure 5. The photographic house of the photoheliograph is at right, with its horizontal tube extending north toward the heliostat. Dome of the 36-inch refractor is in the background. View is looking southwest (no date, but between 1888 and 1907). Photo courtesy Darrell Severinsen, Lick Observatory.

They appear to be by far the most complete photographic record of a transit of Venus to have survived to the present. We know of no plates from the 1874 transit, and the only other collection known to us are the eleven plates that survived from the 1882 Commission expeditions in the collection of the U. S. Naval Observatory, though others may exist elsewhere.

The Lick collection was assembled into a time-lapse movie (see Misch & Sheehan 2004), which is remarkable in making visible an event that no living person has seen, but that has been lying dormant for 120 years in the Lick archive. The series of photographs also has a place of importance in the history of photography, and especially in the then-emerging art of chronophotography – the serial recording of a moving event – being explored in a more deliberate way by Marey, Jansen, Muybridge, and others.

4. Epilogue

It is not entirely clear whether the considerable efforts of the various transit expeditions succeeded in their scientific aim of refining the measurement of the earth-sun distance. Harkness spent years reducing the transit data, but it would appear that Todd himself did not follow up the observations, at least in print.

It is an interesting if sad footnote that Todd, 27 at the time of the transit, is now remembered more as famous cuckold than astronomer. During his absence from Amherst to follow the sun from Mount Hamilton, his beautiful and intelligent wife of three years, Mabel Loomis Todd, author and champion of Emily Dickinson, began a love affair with the poet's brother Austin that would continue for the rest of their lives (for details, see Sheehan & Misch 2004).

Acknowledgements

The authors thank *The Mary Lea Shane Archive* of the Lick Observatory and Darrell Severinsen for the photographic material.

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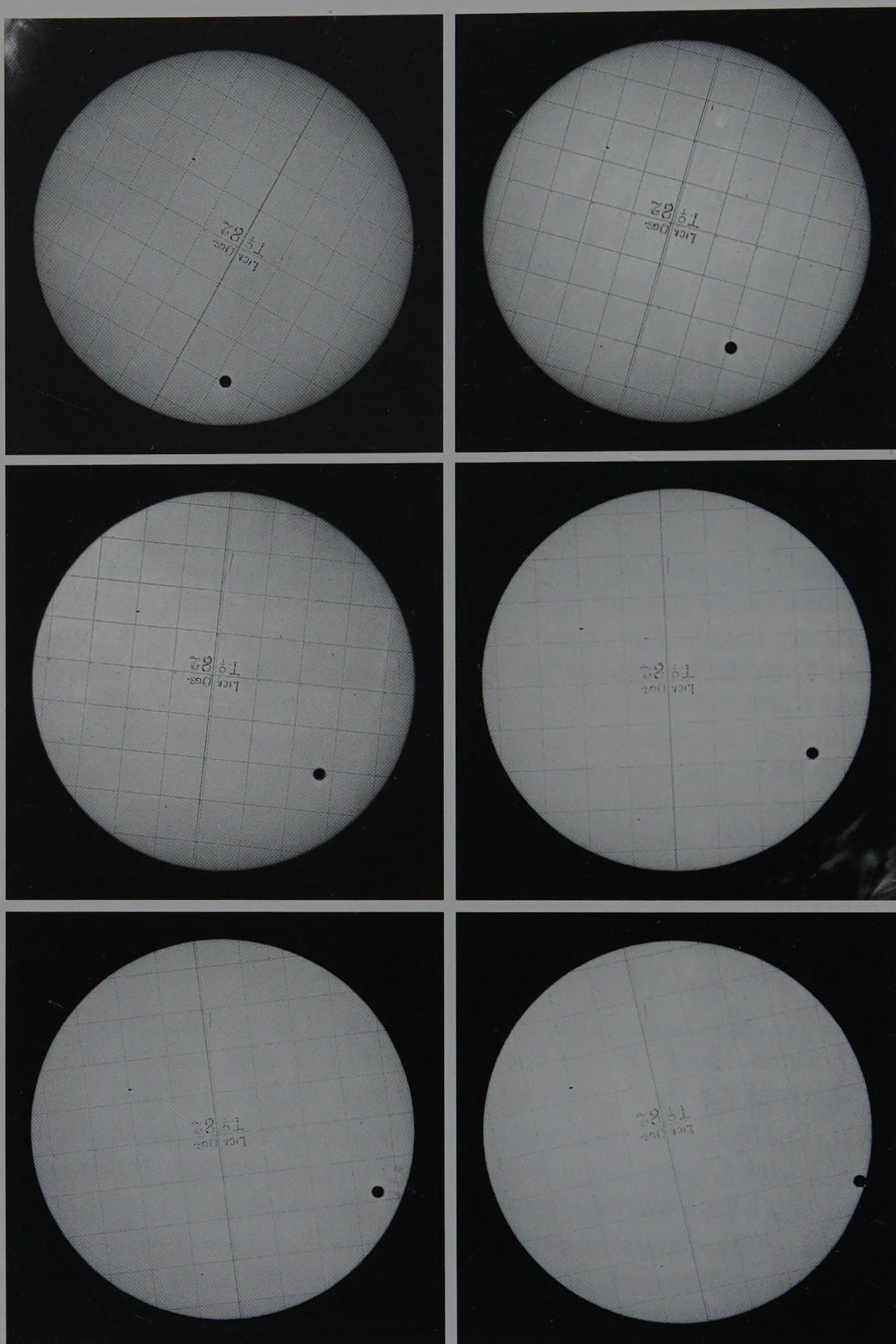

Figure 6. Six of Todd's photographs, from near the beginning to near the end of the transit as visible from Mount Hamilton. From *The Journal of the History of Astronomy.* Copyright UCO/Lick.

ASTRONOMICAL HERITAGES: Astronomical Archives and Historic Transits of Venus
Journal of Astronomical Data, Vol. 10, 7, 2004
Christiaan Sterken, Hilmar W. Duerbeck, eds.

The Nineteenth Century Transits of Venus: an Australian and New Zealand Overview

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Abstract

Because of their fortuitous locations, Australia and New Zealand hosted overseas expeditions, various local government-funded observing teams and a plethora of dedicated amateur astronomers intent on observing the 1874 and 1882 transits of Venus. Even though the ingress phase occurred before local sunrise in 1882, and inclement weather foiled some New Zealand-based observers in 1874 and many sited in Australia in 1882, these trans-Tasman nations collectively were able to play an important role in the quest to determine one of astronomy's fundamental yardsticks: the mean distance from the Earth to the Sun.

1. Introduction

The quest to accurately determine the solar parallax was one of the great issues of world astronomy during the nineteenth century, and the Venus transits of 1874 and 1882 were seen by many as the best method of approach (Clerke, 1893). With a value for this parallax nailed, that basic yardstick of astronomy, the astronomical unit, could be addressed. Ideally, the transit should be observed from sites widely separated in latitude, and, given their fortuitous location on the globe, Australia and New Zealand were collectively to contribute in a manner that was far out of proportion to their combined geographical area and population.

While studies have already been published of some individual Australian and New Zealand transit stations (Orchiston and Buchanan, 1993, 2004; Orchiston, Love & Dick, 2000) and of state-wide Australian efforts (Edwards, 2004; Ellery, 1883; Lomb, 2004; Orchiston 2004b;

Russell 1883, 1892; Todd, 1883) and regional New Zealand programs (McIntosh, 1958), the definitive account of all significant Australian and New Zealand transit observations in 1874 and 1882 has yet to be written. This review is a first step in that direction. As is accepted practice, throughout this paper the terms 'first contact' and 'second contact' will relate to the external and internal ingress contacts respectively, and 'third contact' and 'fourth contact' to the internal and external egress contacts.

2. The 1874 Transit

As Woolf (1959) has brilliantly portrayed, the two eighteenth century transits were the world's first major international scientific projects, but they did not produce the anticipated results. Instead, 'acceptable' published values of the solar parallax ranged from $8''.43$ to $8''.80$, representing a variation in the distance of the astronomical unit of $\sim 6.57 \times 10^6$ km – a totally unsatisfactory situation. This threw the focus on the two nineteenth century transits, and demanded that improvements be made in instrumentation and longitude-determination of the various transit sites. One of the key developments in nineteenth century astronomy was the emergence of photography, and there was an early realization that it had special potential in astronomy (e.g. see Lankford, 1984). Photography was to play a key role during the 1874 transit (Lankford, 1987) – as the following case studies will illustrate.

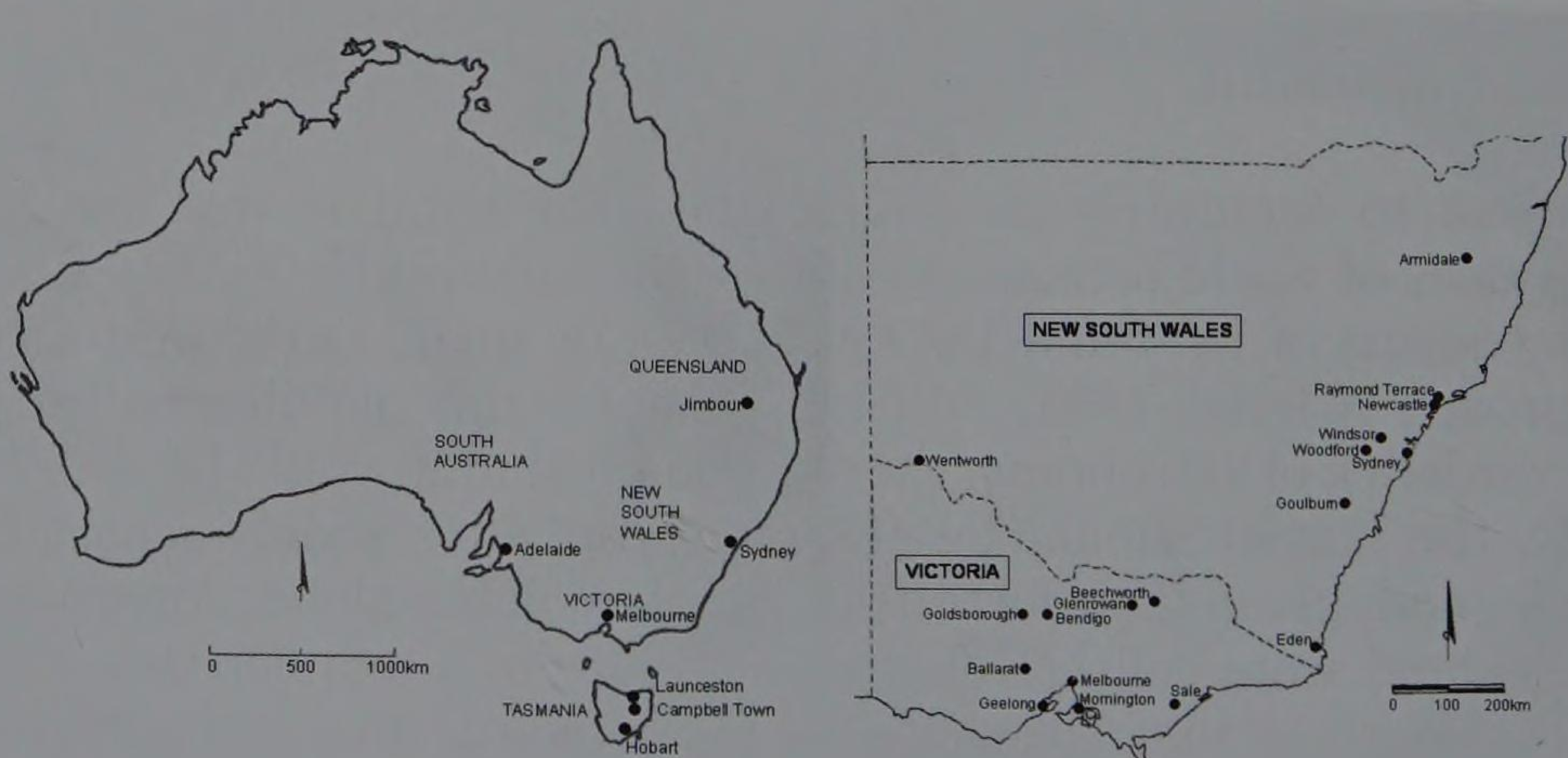

Figure 1. Maps showing Australian (left) and New South Wales and Victorian localities mentioned in the text.

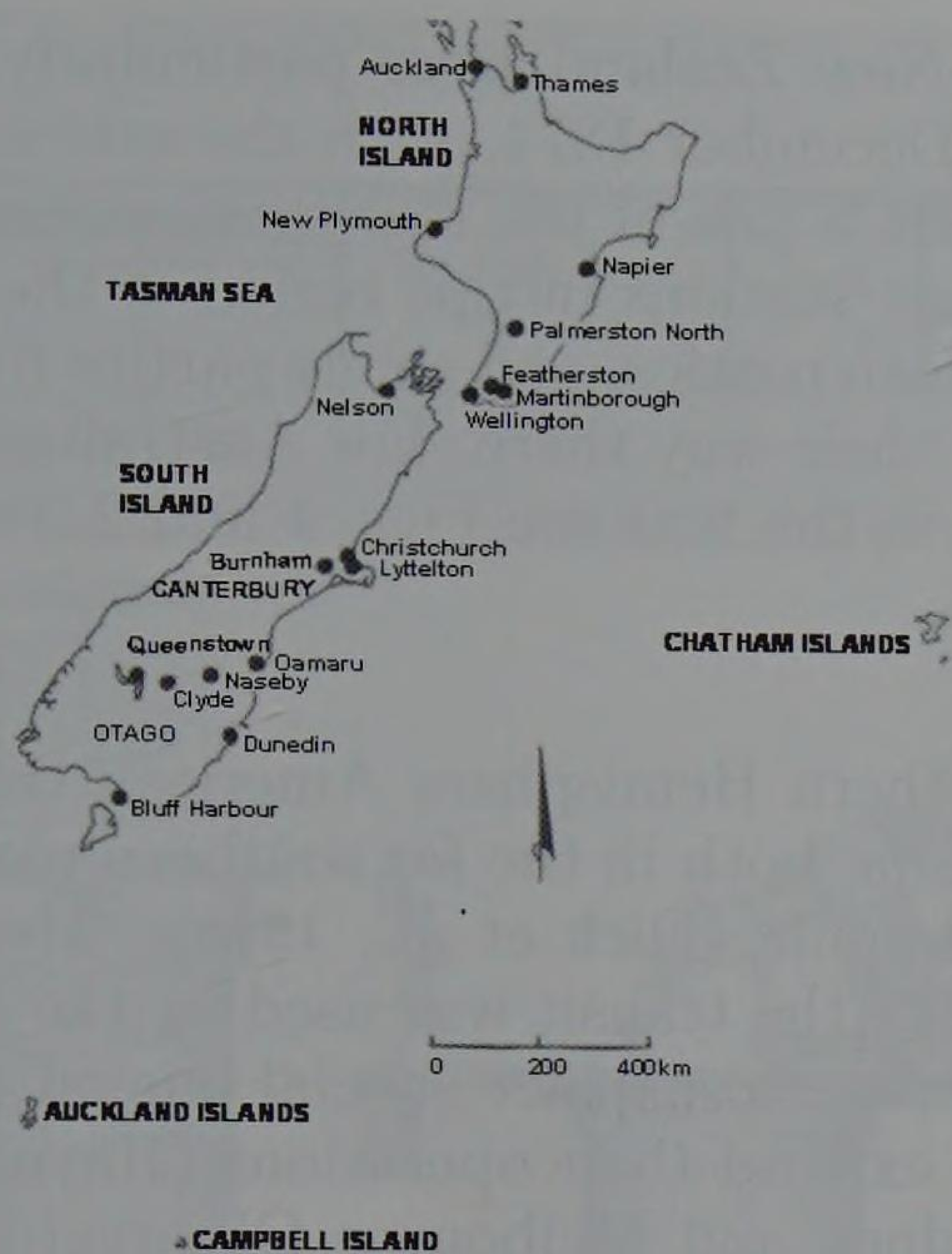

Figure 2. New Zealand localities mentioned in the text.

Figure 3. U.S.S. *Swatara* anchored in Bluff Harbour, New Zealand (Courtesy: Hocken Library, Dunedin).

Australia and New Zealand were particularly favourably-placed for the transit of 9 December 1874, with the entire event visible from both nations, and this is one of the reasons that foreign powers established southern transit stations in this region of the southwest Pacific. Four different American parties, and single parties from Britain, France and Germany found their way there. For Australian and New Zealand localities mentioned in the text see Figs. 1 and 2, respectively.

2.1. Australia

Two of the five Southern Hemisphere American transit parties based themselves in Australia, both in the far southern reaches of the nation, on the island of Tasmania (Dick et al., 1998). Meanwhile, the international significance of the transit was used by the Australian colonial observatories as leverage to extract special one-off funding from their governments and to expand their operations (Haynes et al., 1996; Orchiston, 1988a). Sydney and Melbourne Observatories both mounted successful campaigns involving dispersed transit stations. This was the first chance that these institutions, and Adelaide Observatory, had to play a key role in cutting-edge international astronomy, and it was an opportunity not to be missed. But more than this, the transit captivated public attention (Orchiston, 1997), which is best typified, perhaps, by the report of 10 December in *The Mercury*: In Hobart "Everybody seemed to have suddenly discovered what an interesting study astronomy was, and to have developed an intimate acquaintance with matters pertaining to the great luminary of day and the inferior planet ..." (The transit of Venus, 1874e). The transit was one of the catalysts that caused a remarkable growth in Australian amateur astronomy during the last quarter of the nineteenth century (see Haynes et al., 1996; Orchiston, 1989; 1998a).

International Expeditions. Campbell Town: the U.S. Expedition.

All five southern hemisphere U.S. transit parties were transported on U.S.S. *Swatara* (Fig. 3), but when the Crozet party reached their destination a landing proved impossible and they were forced to continue on to Hobart (Newcomb, 1880: 18). There they decided to accept the invitation of Dr William Valentine to base their transit station at his home in Campbell Town, ~130 km north of Hobart (Orchiston and Buchanan, 1993). The location of the site was: longitude = 09h 50m 00.1s W of Greenwich, and latitude = 41° 55′ 42.″9 S (Newcomb, 1880: 21), and members of the transit party were Captain C.W. Ray-

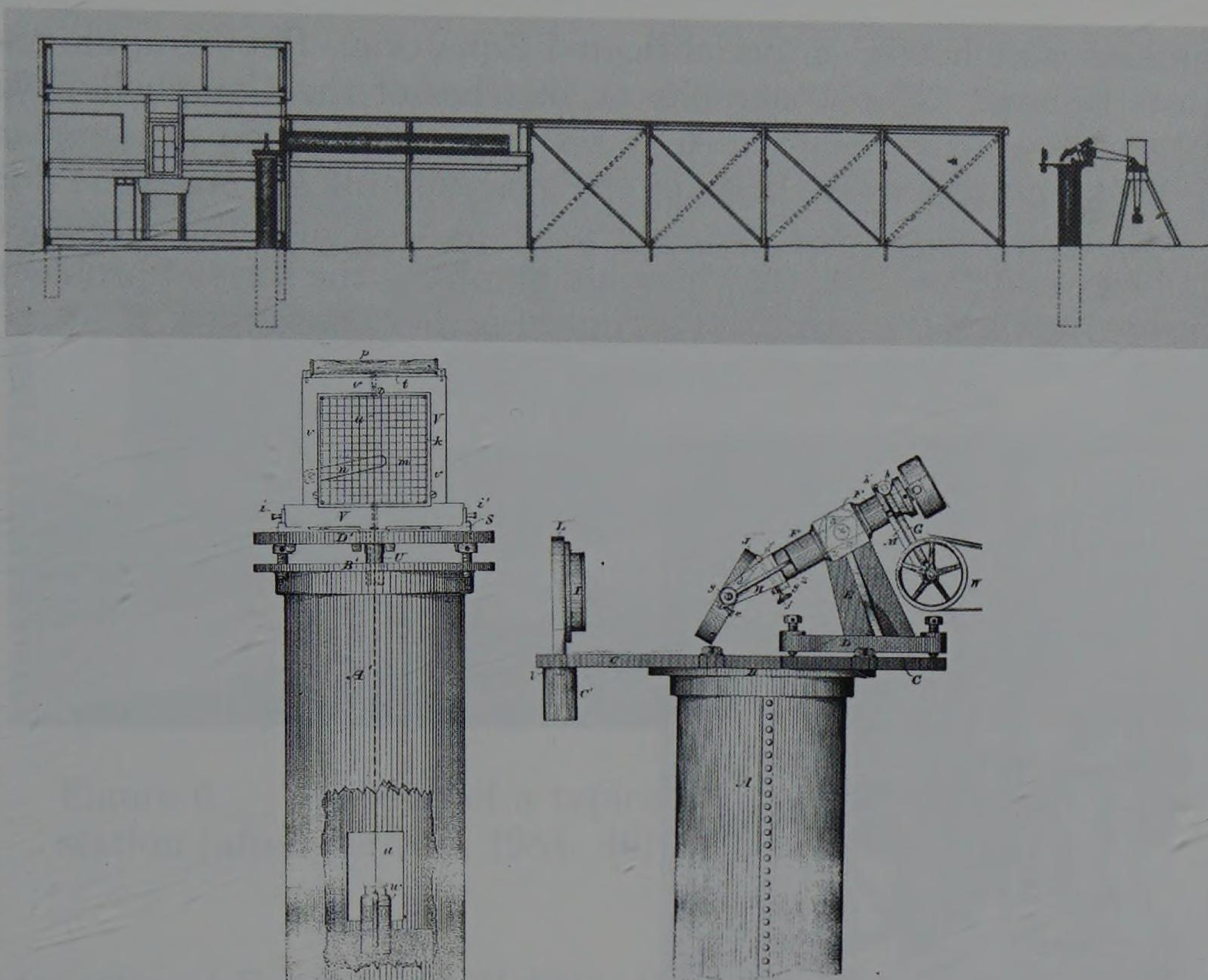

Figure 4. The horizontal photographic telescope used by the U.S. transit parties. At the top is a schematic overview of the instrument, while close-ups of the plate-holder and heliostat are shown bottom left and bottom right respectively (after Newcomb, 1880).

mond (Corps of Engineers), his Assistant Astronomer, Lieutenant S.E. Tillman (also from the Corps), and three photographers, W.R. Pywell, J.C. Campbell and Theodore Richey (Dick, 2003: 255). In addition, three local men assisted in the transit compound; one of these, Alfred Barrett Biggs, later went on to make a name for himself as Tasmania's foremost late-nineteenth century astronomer (Orchiston, 1985).

The astronomical instruments used at Campbell Town were basically the same as those found at the other U.S. 1874 transit stations, and comprised: a horizontal photographic telescope (Fig. 4), a Stackpole broken-tube transit telescope (Fig. 5), a 12.7-cm (5-in) Alvan Clark refractor, a sidereal clock by Howard, and Negus and Porter chronometers. And as at other U.S. transit stations, some of these in-

struments were housed in prefabricated Equatorial, Photographic and Transit Houses. No photographs or sketches of the Campbell Town transit station exist, but Fig. 6 shows the configuration of a typical U.S. 1874 transit station. Perhaps the most notable feature is the horizontal photographic telescope, evidence of American faith in this new technology and the belief that it would eliminate the sorts of problems connected with naked-eye observations of earlier transits.

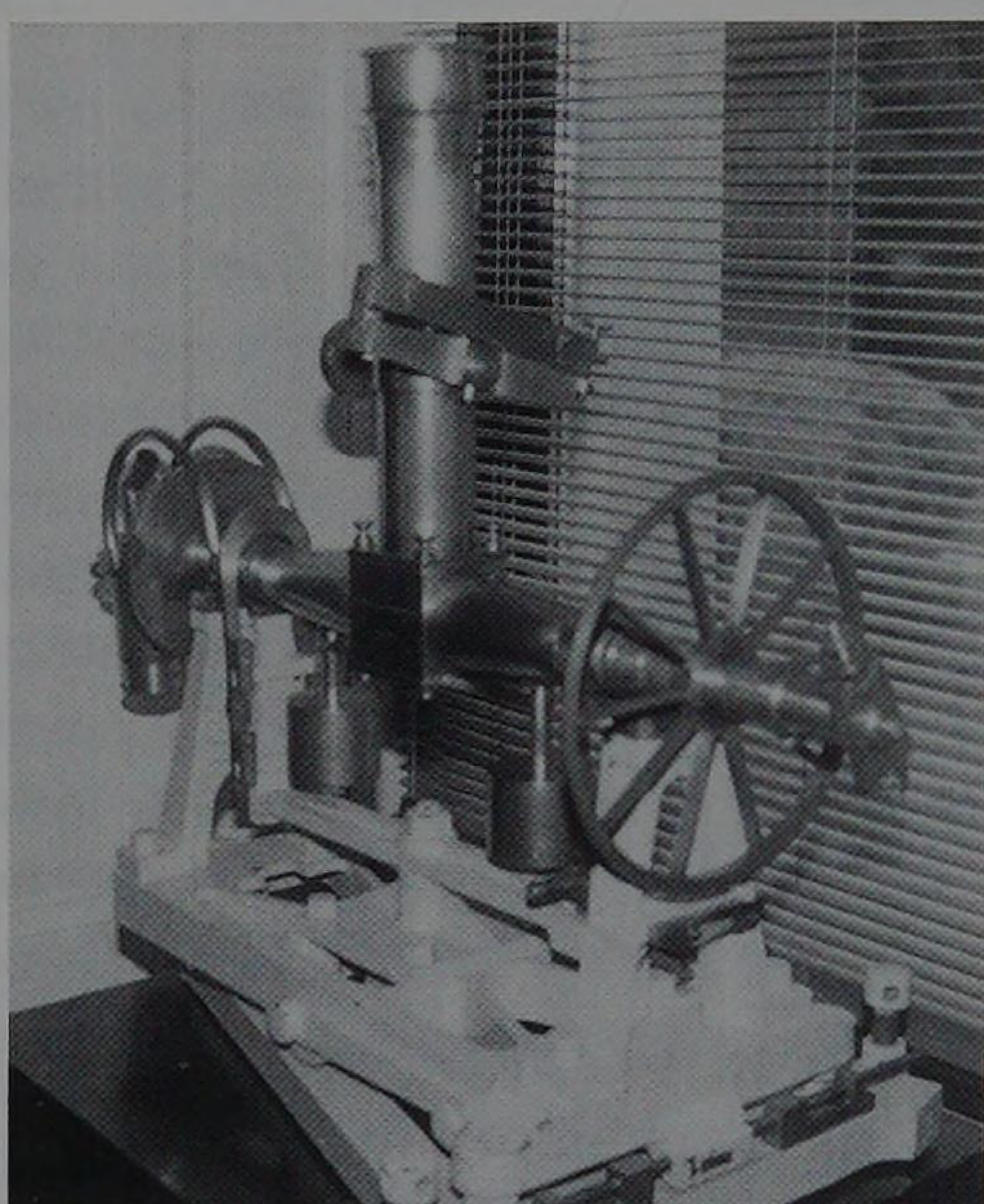

Figure 5. The Stackpole broken-tube transit telescope (Orchiston Collection).

At Campbell Town the morning of 9 December dawned cloudy, and it soon began raining heavily. However, about forty minutes after first contact the rain suddenly ceased, and Venus was visible on the face of the Sun. The photographers set to work, and continued to expose plates for the rest of the transit, apart from those intervals when the rain or heavy clouds returned. Dick (2003: 259) states that fifty-five photographs were obtained, but a Tasmanian newspaper at the time listed the number as 120 (*The Tasmanian Tribune*, 1874). One of these is reproduced in Fig. 7. In addition, Raymond used the Clark telescope to make the following rather poor observation of the third contact: "... dim and cloudy; planet pear-shaped at the time of contact; limb of Sun unsteady; not a satisfactory observation on account of clouds. (Newcomb, 1880: 154). Given the unfortunate start to the day, by the end of the transit Raymond felt that he "... had seized victory out of jaws of defeat." (The transit of Venus, 1874e).

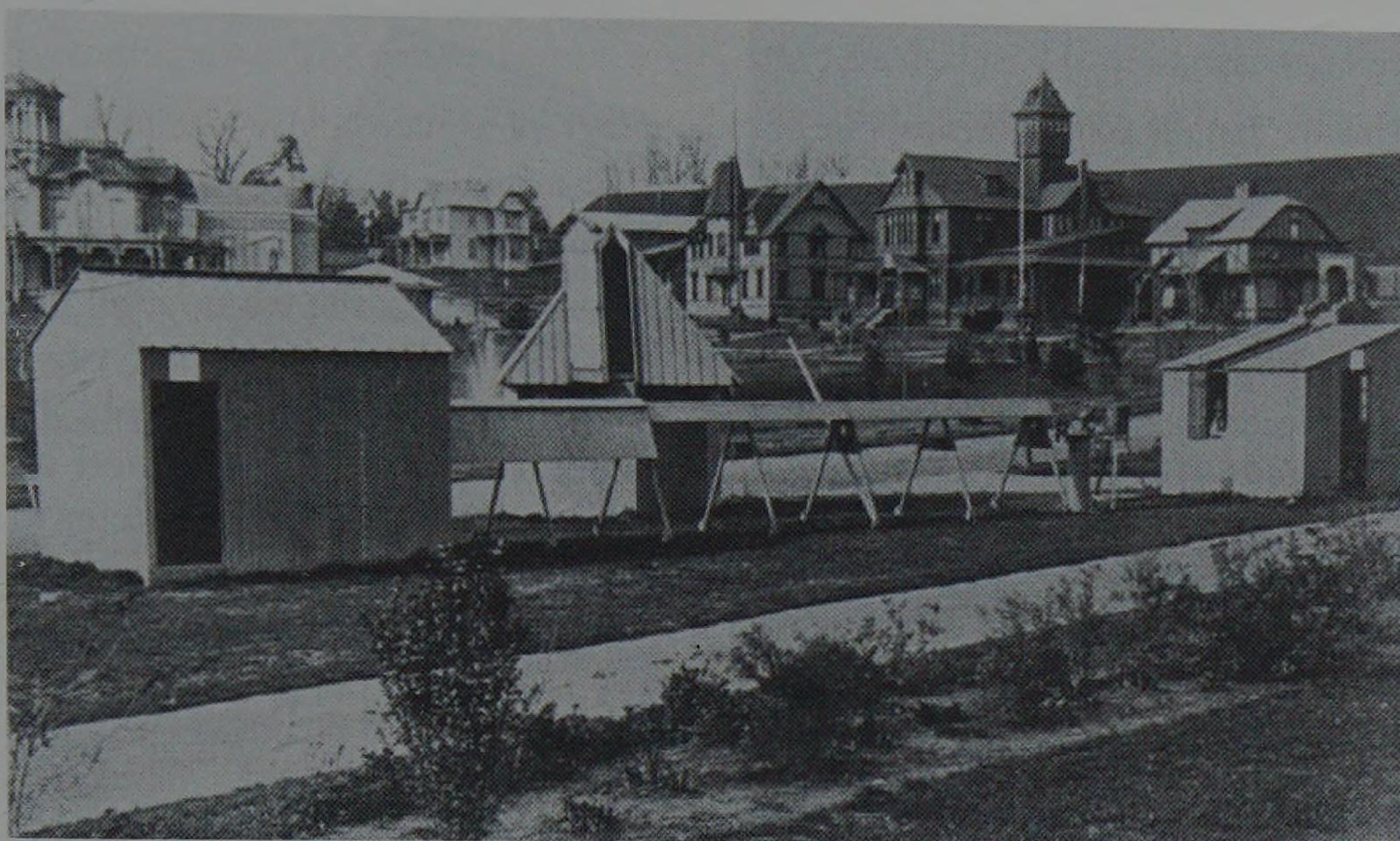

Figure 6. Mock-up of a typical U.S. 1874 transit of Venus station (after Herman, 1984: 46).

International Expeditions. Hobart: the U.S. Expedition.

The U.S. transit party in Hobart, the Tasmanian capital, fared little better than their nearby counterparts at Campbell Town. Furnished with similar instruments, Professor William Harkness (U.S. Navy), his Assistant Astronomer, Leonard Waldo, and the three photographers, John Moran, W.H. Churchill and W.B. Devereux (Dick, 2003: 255), were assisted by four volunteers, Dr. Kirshner, Mr. Stephenson and Mr. Wilkins from the U.S.S. *Swatara*, and Major McMahon of the Indian Royal Artillery (The transit of Venus, 1874e). The transit station was set up at Barrack Square in suburban Hobart, adjacent to the soldiers' monument (see Fig. 8). This has a longitude of 09h 45m 20.5s W and a latitude of 42° 53′ 24.″6 S. (Newcomb, 1880: 21). The layout of the station is shown in Fig. 9.

Transit day also was an initial disaster, and it was only three hours into the transit that the sky cleared enough for observations to be made. The first photographs were taken at 2h 45m local time, and over the next forty-three minutes Moran, Churchill, Devereux and the volunteers succeeded in taking thirty-nine exposures of Venus on the Sun's disk. Later "... the quick exposure apparatus was brought into use, and 74 pictures, including a photograph of the last contact, were taken

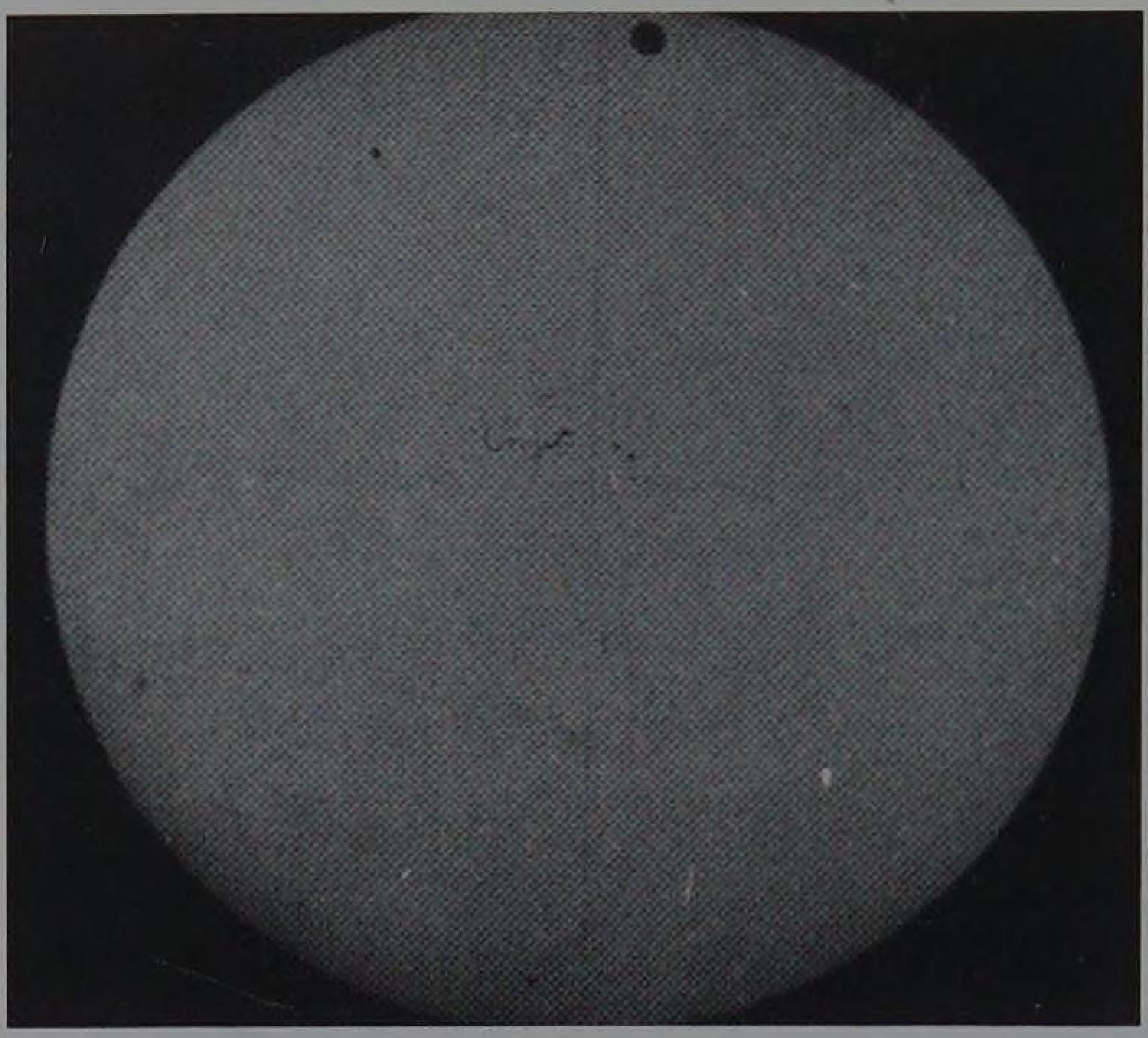

Figure 7. Photograph of Venus in transit obtained at Campbell Town (Courtesy: Queen Victoria Museum & Art Gallery, Launceston).

Figure 8. The Soldier's Monument and part of the Barrack Square transit station in Hobart (Courtesy: Tasmanian Museum & Art Gallery, Hobart).

between 10 minutes to 4 and 12 minutes past 4, when the final contact took place." (The transit of Venus, 1874e). Another local newspaper elaborates slightly: "The American party at the Barracks succeeded in taking 160 photographs by the wet collodion process, *of which 113 were considered first-rate*." (*The Tasmanian Tribune*, 1874; my italics). This is hard to reconcile with Dick's (2003: 257–259) overview where just 39 photographs are listed in Table 7.4. Be that as it may, the clouds were quite dense by the time of the fourth contact, and Harkness was not able to see either of the egress contacts through the Clark telescope. Nonetheless, a local newspaper reported that he was "... very well satisfied with the results that were obtained, taking into consideration the unfavourable state of the weather." (*The Tasmanian Tribune*, 1874).

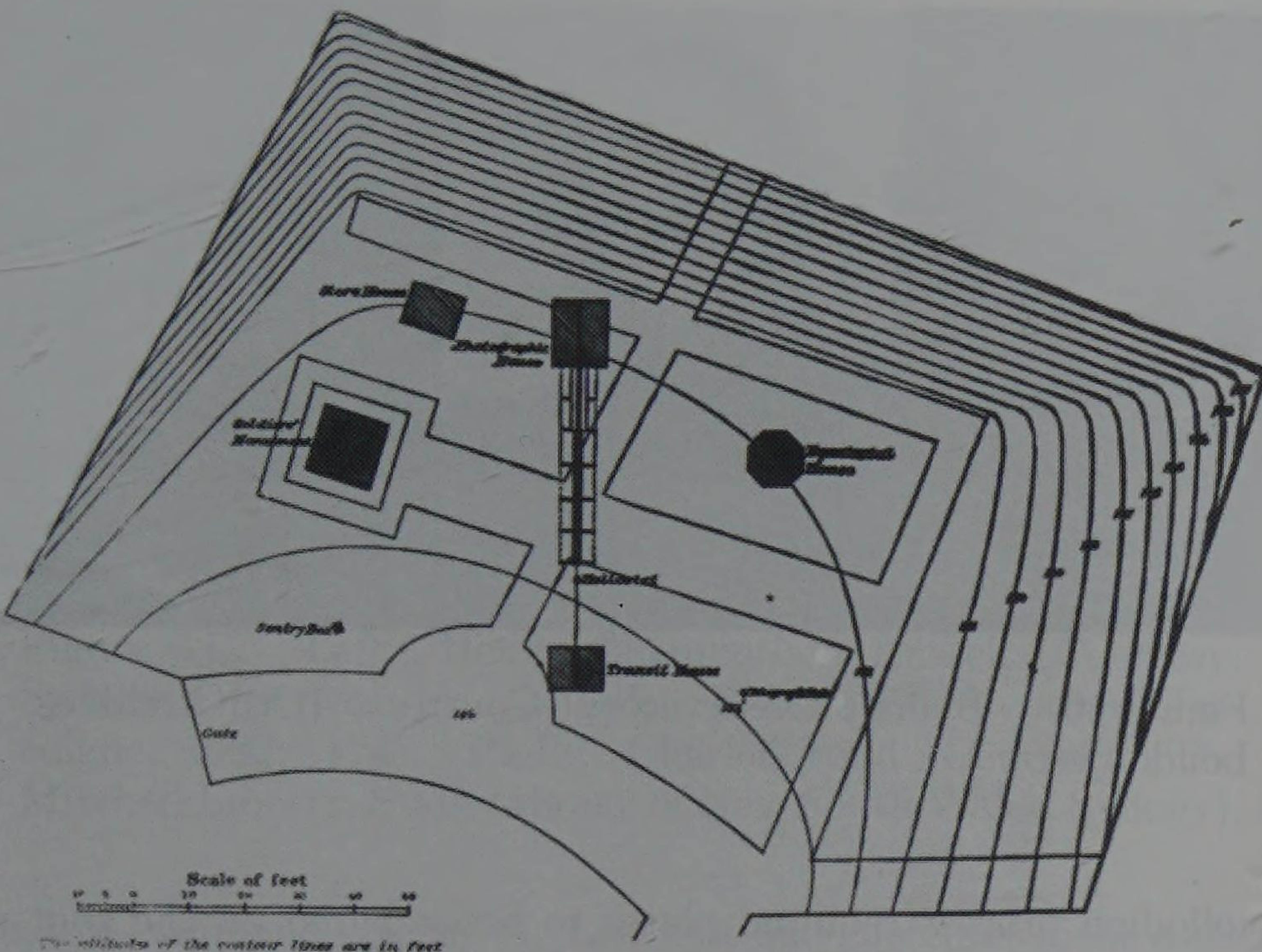

Figure 9. Layout of the Barrack Square transit station (after Dick, 2003).

This contrasts with Newcomb's (1881) evaluation, which suggests that Harkness was profoundly disappointed with the overall scientific outcome of the expedition.

Colonial Observatories. Sydney Observatory.

Sydney Observatory (Fig. 10) was founded in 1858 on the shores of Sydney Harbour, and from the start its multifarious functions included astronomy, time-keeping, meteorology and tidal recording (Orchiston, 1998b). The observatory's third director was Australian-born, Henry Chamberlain Russell (Fig. 11) (Bhathal, 1991), and it was he who planned the 1874 transit campaign involving four different observing stations and successfully lobbied the New South Wales Government for the requisite funding – the very considerable sum of £1,000 (Russell, 1873). Astronomical photography was still in its infancy at this time (see Lankford, 1984), and it was to play a key role at most of these transit stations. As Haynes et al. (1996: 57) remind us, this was a technological challenge and non-trivial exercise, for "... the then-current

Figure 10. Sydney Observatory (Courtesy: RAS Archives, London).

wet-collodion process required plates to be prepared on the spot and processed immediately. The problems of preparing and developing large numbers of plates in a blacked-out tent, in remote regions of New South Wales and in the heat of December must have been daunting." Russell succeeded in manning the stations by using his own staff, selected amateur astronomers, and colleagues from other Government departments – including the Lands Department (see Fig. 12). This was at a time when there were still amiable relations between Sydney Observatory and the Lands Department; had the transit occurred ten years later such collaboration would have been all but impossible (see Orchiston 1987).

Russell queried Airy on the most appropriate observing program and received the following advice: "No better arrangement for observing the Transit of Venus can be made than that which you propose, namely, to observe by eye at the telescope the completed ingress and the beginning of egress (which I fully expect to be the most accurate observation of all ...) and fill up the time by taking photographs. But do not let photographs interfere with the integrity of the eye-observations." (Airy, 1873). He then provided Russell with several pages of photographic "cautions". All of this advice was to prove invaluable to Russell as he planned and fine-tuned the ambitious Sydney Observatory transit program.

The primary Sydney Observatory observing station was the Observatory itself in central Sydney, and Russell was assisted there by his

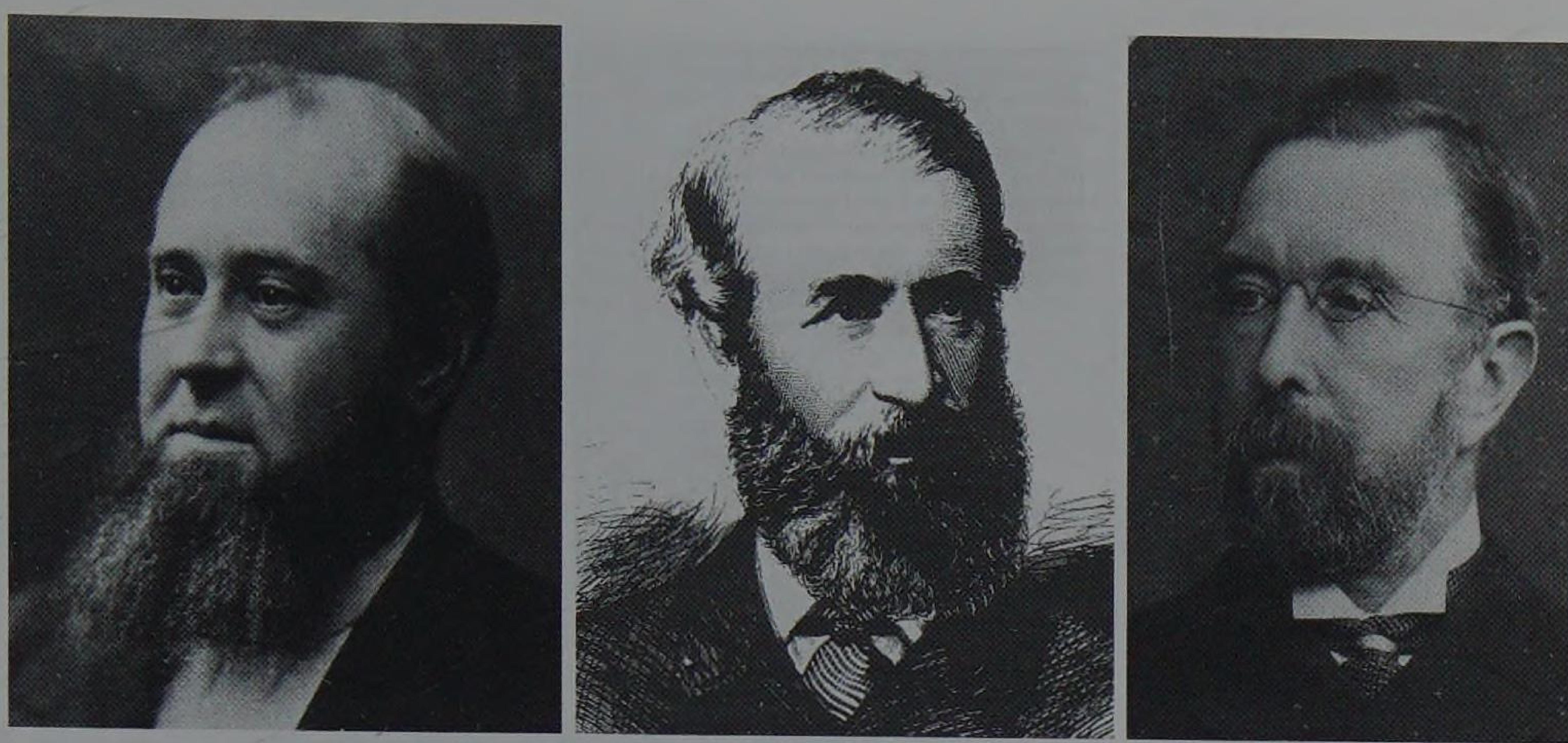

Figure 11. Left: Henry Chamberlain Russell (Courtesy: Sydney Observatory). Middle: Robert Ellery (after Gascoigne, 1992: 174). Right: Charles Todd (Courtesy: The Mitchell Library, State Library of New South Wales, Sydney).

second-in-command, Henry A. Lenehan and meteorological assistant, Edwin G. Savage (see Fig. 12). Instruments at their disposal were an impressive new 29.2-cm (11.5-in) Schroeder refractor acquired just for the occasion (Fig. 13), a 12.1-cm (4.75-in) Troughton and Simms refractor, a 26-cm (10.25-in) Browning-With reflector loaned for the occasion by local amateur astronomer, J.U.C. Colyer, together with a chronograph, astronomical clocks and chronometers. December 9 dawned dull in Sydney, but by 9 a.m. the clouds had disappeared, and the sky remained clear for the transit. Russell was at the Schroeder refractor, which was reduced to 12.7-cm (5 inches) for visual observing and 15.2-cm (6 inches) for photography, and with difficulty he timed all four contacts. Nearly twenty minutes after first contact he first observed what he called a halo:

> "... the planet had been getting gradually more conspicuous both on and off the Sun's limb, and my attention had been principally directed to the cusps, to detect, if possible, any phenomena like the formation of the drop, but nothing was seen, and when taking a general look at the time noted, I first observed the halo round that part of the planet, not on the Sun. It was very remarkable and beautiful, like a fringe of green light through which the faintest tinge of red could be seen [he was using green and blue filters in the eyepiece]; it was densest near the planet, and seemed to shade

Figure 12. Observers involved in the Sydney Observatory 1874 transit of Venus program (after Russell, 1892: Frontispiece).

> off to nothing with a diameter estimated at one second of arc. It did not appear solid, like the disk of the Sun, but like light in a dense vapour. As ingress proceeded the halo became more conspicuous, but I did not observe any want of uniformity in its diameter, and it at all times terminated at the Sun." (Russell, 1883: 50–51).

Drawings by Russell of the 'halo' are reproduced here in Fig. 14. Nothing remarkable was observed immediately after second contact, and

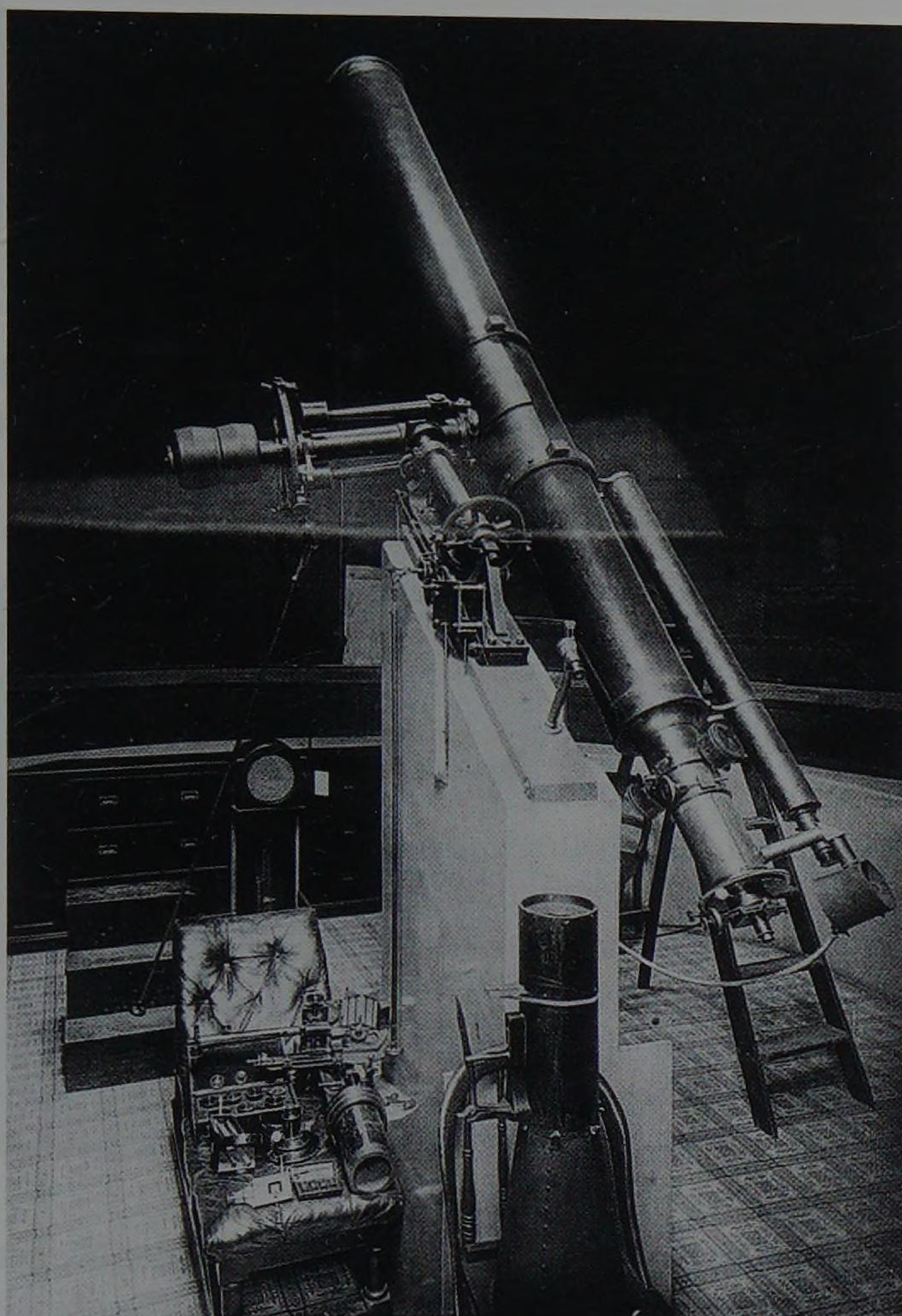

Figure 13. Sydney Observatory 11.25-in Schroeder refractor (after Russell, 1892: Plate XXXII).

about nine minutes after this event Russell substituted the camera for the eyepiece and over the next three hours and ten minutes succeeded in taking 190 photographs of Venus on the Sun's disk, "... a clear and beautiful record of the Transit." (Russell, 1883: 51).

Lenehan was using the smaller refractor, stopped down to 10.2-cm (4 inches), and like Russell found it hard to accurately determine the times of the two ingress contacts. At about the time that Russell first noticed the 'halo', Lenehan (1883: 54) fancied he saw the illuminated outer edge of the planet (off the Sun), "... but I was not perfectly clear on that point." Seven and a half minutes later he noted that "... the drop apparently formed, being to my mind as if the edge of the

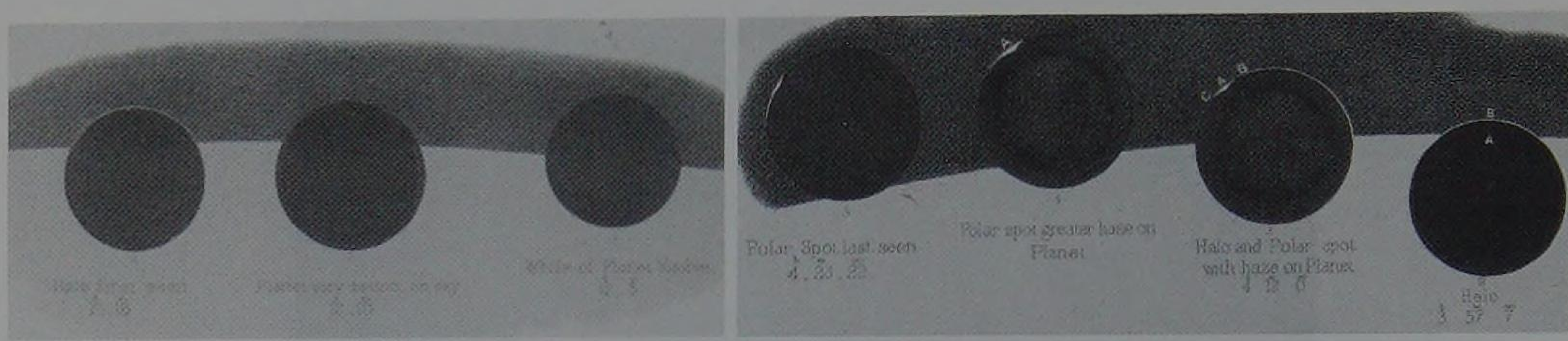

Figure 14. Russell's drawings of the ingress (left) and egress (right). After Russell, 1892: Plate XXVII and XXV, resp.).

planet was losing its curvature, *but I later found I was mistaken, as no formation of the drop was apparent.*" (*ibid.*; my italics). Soon after second contact Lenehan joined Russell in participated in the photographic program, only returning to the telescope as third contact approached.

The third Sydney Observatory observer was Edwin Savage, and as a meteorologist and someone who was not familiar with telescopes – let alone reasonably large reflecting telescopes – he missed the first contact. Immediately after second contact he looked out for the black drop, and "As the planet advanced on the Sun's disk a little way, this shading still connected the planet with the Sun's edge, but that portion of it nearest to the planet showed indications of fading away gradually, until at length it disappeared altogether, without any sudden break whatever ..." (Savage, 1883: 56).

All three observers also saw the first egress contact, but only Lenehan and Savage were able to time the final egress contact. Russell (1883, 52) saw no sign of the black drop, but several minutes after third contact he "... saw the outline [of Venus] off the Sun with the halo round it, exactly similar to that seen at ingress, and now as then only on that portion of the planet which was off the Sun ..." Then followed intervals of variable seeing, and the halo almost disappeared. As a result, Russell changed the blue eyepiece filter for one of lighter tint, and immediately "... saw the halo distinctly all round the part off the Sun ... the halo was for the first time seen irregular in diameter, it seemed considerably broader at the North pole of the planet." (Russell, 1883: 53). Eventually, only this north polar illumination was all that was visible, and it subsequently faded away as the seeing worsened. Russell's drawings showing changes in the nature of the 'halo' are reproduced in Fig. 14. Clouds and haze prevented Russell from making precise observations of the fourth contact.

At egress, Lenehan had a quite different initial view of the transit. As third contact approached "The planet stood out on the Sun's disk

with a clear and sharp outline, with a luminous appearance or halo outside it, about one-third of the diameter of the planet being a greenish colour, the outer edge being of an orange shade, as if the planet had an atmosphere [see Fig. 15]. The sky was clear [at this time], and the following observations were made under very favourable circumstances." (Lenehan, 1883: 55). He then tried to time third contact, and again he fancied he saw the black drop. The halo then appeared and, like Russell, Lenehan subsequently "... noticed a spot of light on the preceding limb of the planet ..." (*ibid.*; cf. Figs. 14 and 15). The transit ended when Lenehan timed the fourth contact.

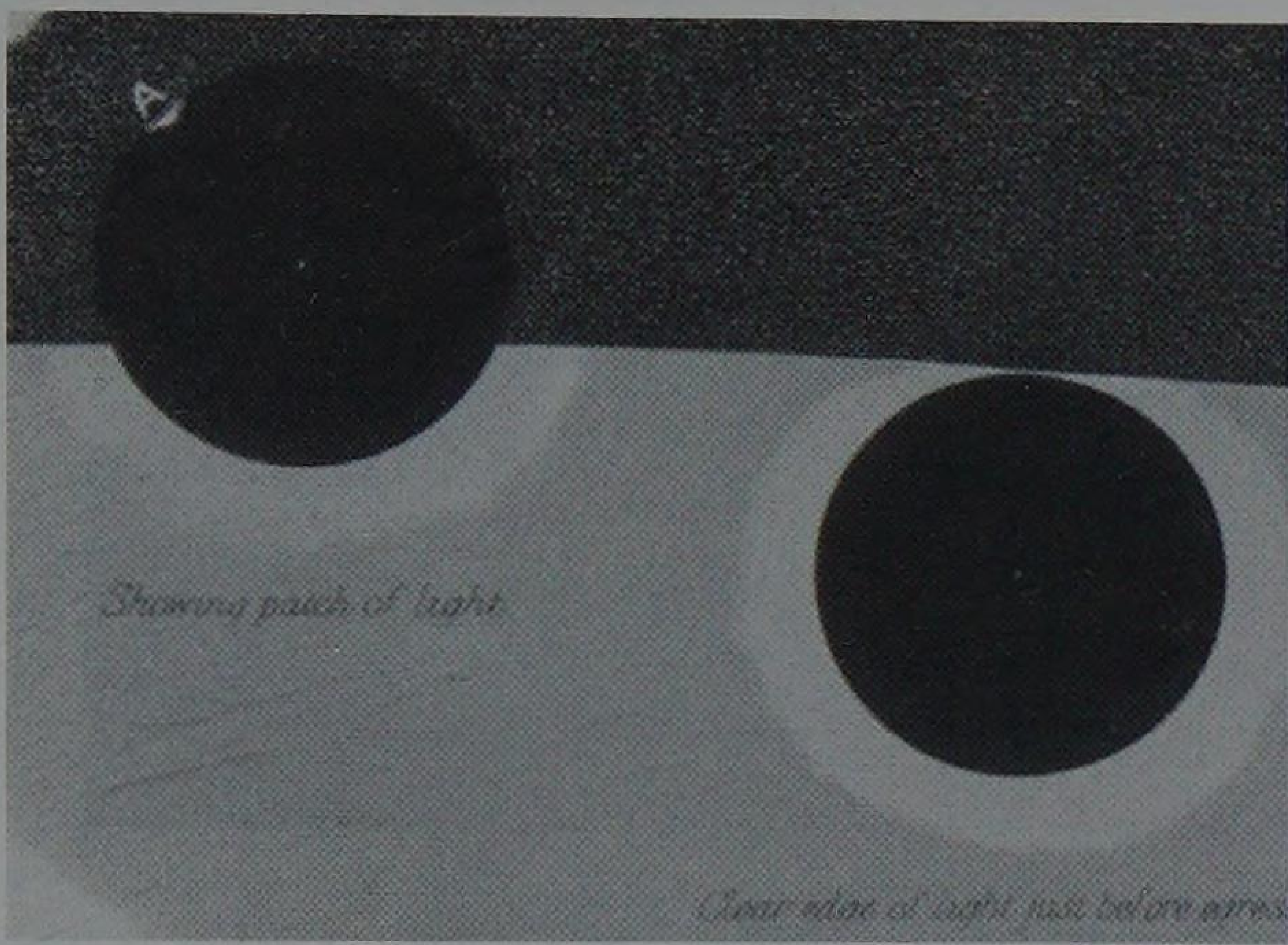

Figure 15. Lenehan's observations of the egress (adapted from Russell, 1892: Plate XVII).

Savage, meanwhile, continued to be troubled by the large reflector and missed the third contact. After this, he "... did not see any outline of the outer edge of the planet during egress." (Savage, 1883: 57), but he did notice a momentary flash of light similar to the 'polar spot' reported by Russell and Lenehan (see Figs. 14 and 15), and he did time the final contact. Between ingress and egress, he helped Russell and Lenehan with the photography, recording the times when the various photographic plates were exposed.

The closest country transit station to Sydney Observatory was located at Woodford in the Blue Mountains, about 85 km due west of Sydney (longitude = 10h 01m 52.71s E; latitude = 33° 43′ 49″ S) and at an altitude of about 670 metres. The station itself was situated on the 'mountain retreat' of A. Fairfax, a keen amateur astronomer and successful Sydney businessman, and included a prefabricated wooden observatory, two tent observatories and a large conventional tent (Fig. 16). Instruments used were a 10.2-cm (4-in) Dallmeyer photoheliograph (Fig. 17), a 7.6-cm (3-in) Cooke refractor, and Fairfax's 12.1-cm (4.75-in) equatorially-mounted Schroeder refractor – known for its outstand-

ing optics (see Russell, 1872) – stopped down to 10.2-cm (4 inches), a portable transit telescope, a sidereal clock, a Frodsham chronometer, and a chronograph (Adams, 1883: 61). As at all three country transit stations, reference time signals were supplied telegraphically from Sydney Observatory immediately before and after the transit. Making up the Woodford observing party were the Surveyor-General, P.F. Adams, aided by L. Abington Vessey and Eccleston DuFaur from the Lands Department, noted Sydney amateur astronomer, George D. Hirst, a Mr Bischoff (who served as photographer) and two carpenters (see Fig. 12).

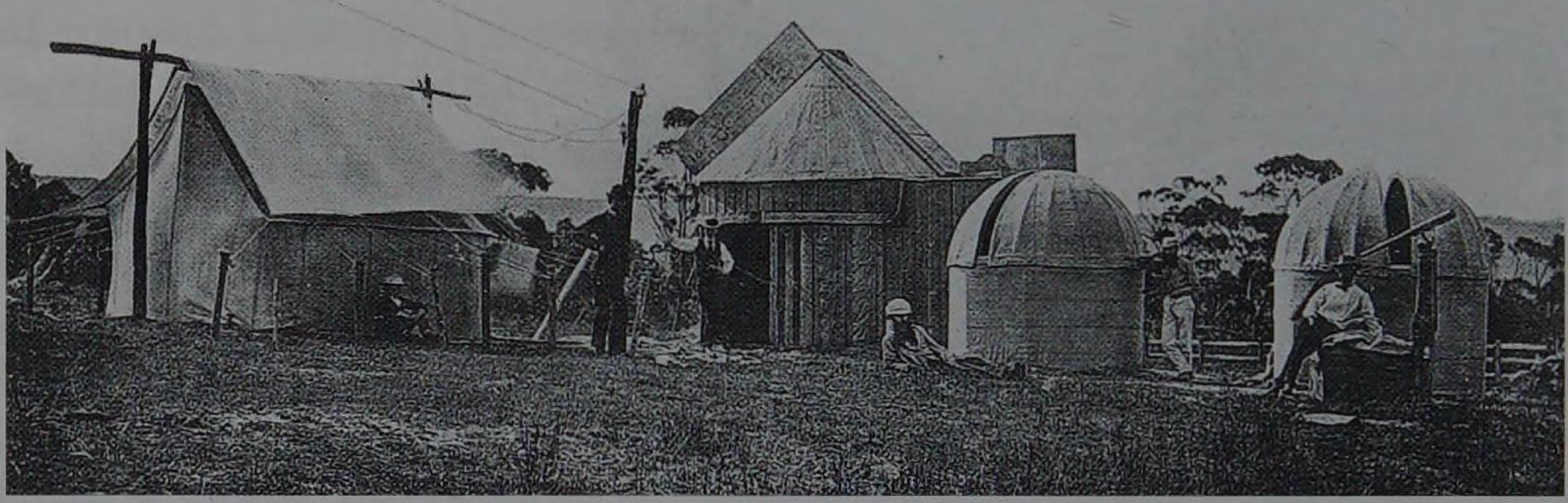

Figure 16. Woodford transit station (after Russell, 1892: Plate XXXV).

Vessey was charged with observing the transit with the Fairfax refractor. At ingress, "... a gust of wind, causing the telescope to vibrate fully half the diameter of *Venus*, prevented a clear view of the phenomena, and the exhaustion caused by heavy night work, in giving assistance with the adjustments of the Photoheliograph, brought about a certain nervousness in the observer at the critical moments, which was not lessened by the totally unexpected nature of the phenomena that occurred." (Vessey, 1883: 64). Nevertheless, around half way between first and second contacts, "... a slight halo 3″ or 4″ (0h 7m 02 Mean Time) within the disk of the planet was seen extending about 60° on each side from the limb of the Sun, and resembling a gradually fading line of dots about 2″ wide (Plate III. Fig. 2)." (Vessey, 1883: 65). Vessey's drawing is reproduced here in Fig. 18 (extreme left). About eight and a half minutes after the halo first appeared, Vessey noticed there was a distinct ring of light round that portion of Venus that was still off the Sun (see the two right-hand drawings in Fig. 18), and this persisted almost up to the time of second contact.

Although not an official member of the transit party, Fairfax (1892) assisted where necessary, and also had a chance to briefly look at Venus through his own telescope during the ingress phase. He, too, noticed the ring of light round that section of Venus still off the Sun's disk. This took the form of "... a most brilliant line, which was very narrow ... It appeared as if Venus were surrounded with white and red flames mixed and so close together that they formed a continuous ring which was probably less than 1/50 of the diameter of Venus across." A rather fanciful pictorial rendition of this is presented in Russell, 1892 (Plate XXX).

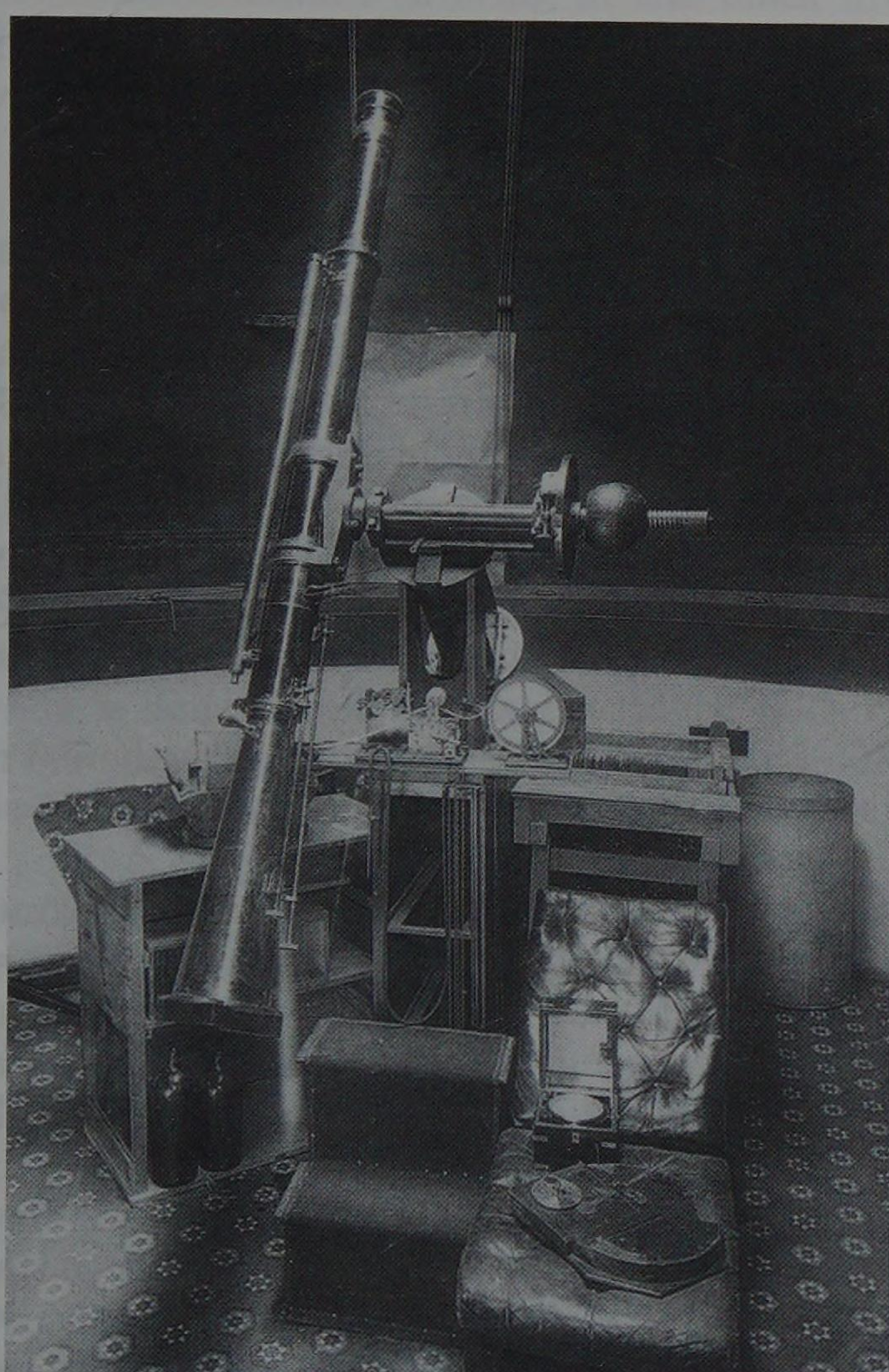

Figure 17. The Dallmeyer photoheliograph at Woodford (after Russell, 1892: Plate XXXIII).

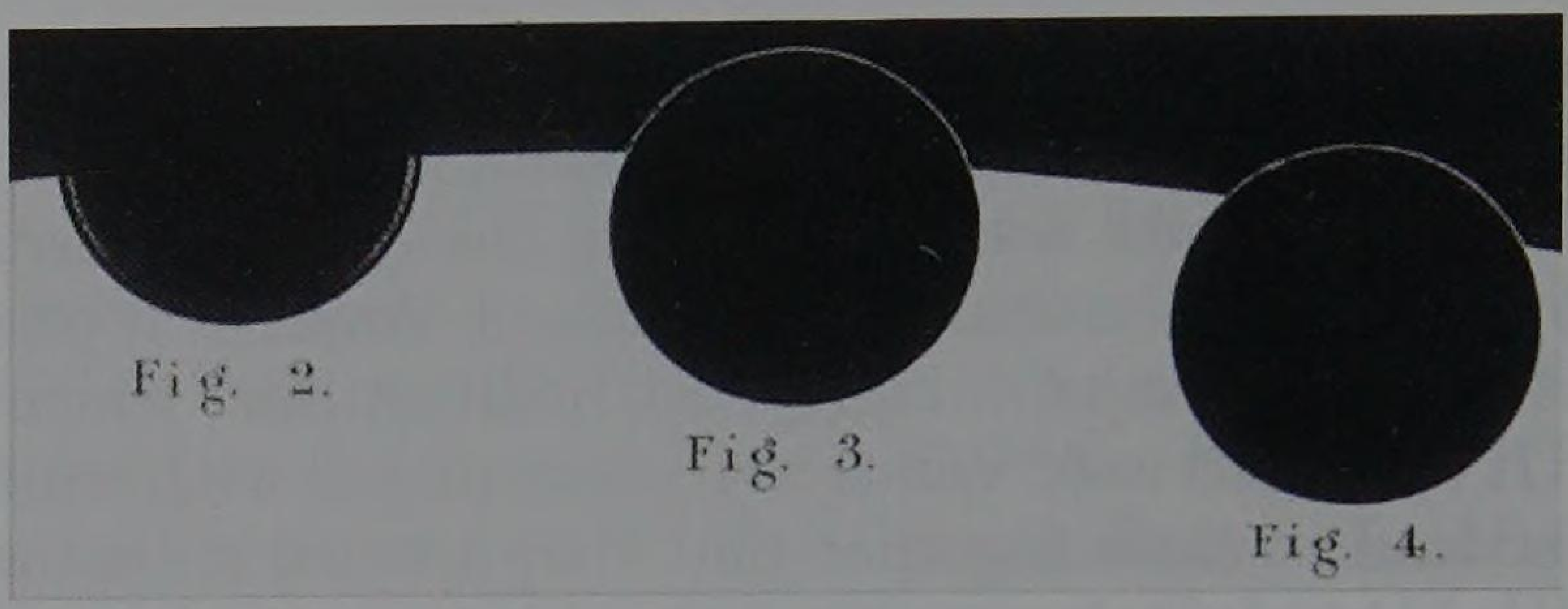

Figure 18. Vessey's egress drawings (adapted from Vessey 1883: Plate III).

During the ingress contacts, Hirst took photographs with the Dallmeyer photoheliograph, but between plates he observed the Sun through the astrograph's 3.8-cm (1.5-inch) finder. After second contact, he clearly saw the black drop (see Fig. 19), and about five seconds later began exposing Janssen plate number 5, expecting to document this famous feature. But he was to be disappointed: "On getting the plate through, however, it showed nothing of what I had so distinctly observed a few seconds before." (Hirst, 1883: 71).

Vessey was also observing at this time, but he did not see the black drop, observing instead an "... atmospheric ring on the disk of the planet ... and gradually shading off towards the centre, to be traced all round, giving Venus an appearance of relief like an oblate spheroid, or rather a flattened dome standing away from the Sun, the radius of the flattened part being about half that of the planet ..." (Vessey, 1883: 65). DuFaur (1892) observing with the 7.6-cm telescope at full aperture, timed the second contact, and failed to see the black drop.

Midway through the transit Hirst happened to look at Venus with Fairfax's refractor and was surprised to see that "... it was surrounded by a narrow fringe of dull red light ... I used a neutral tint glass, so that the red colour cannot be attributed to it." (Hirst, 1892: 21). This unusual feature, which Hirst saw for only a minute, is illustrated in Fig. 19.

At egress, Vessey and Hirst both expected to see the black drop, but only Hirst (1883: 72) was successful: "... I went to the finder, and to my astonishment saw that the drop had formed, appearing about as long as the radius of the planet." All Vessey (1883: 66) noticed was a "... silvery ring of light round the planet ... [which] was carried out on the sky by the slow motion of the planet." and this persisted until after third contact (cf. Fig. 18). Hirst was an experienced and talented

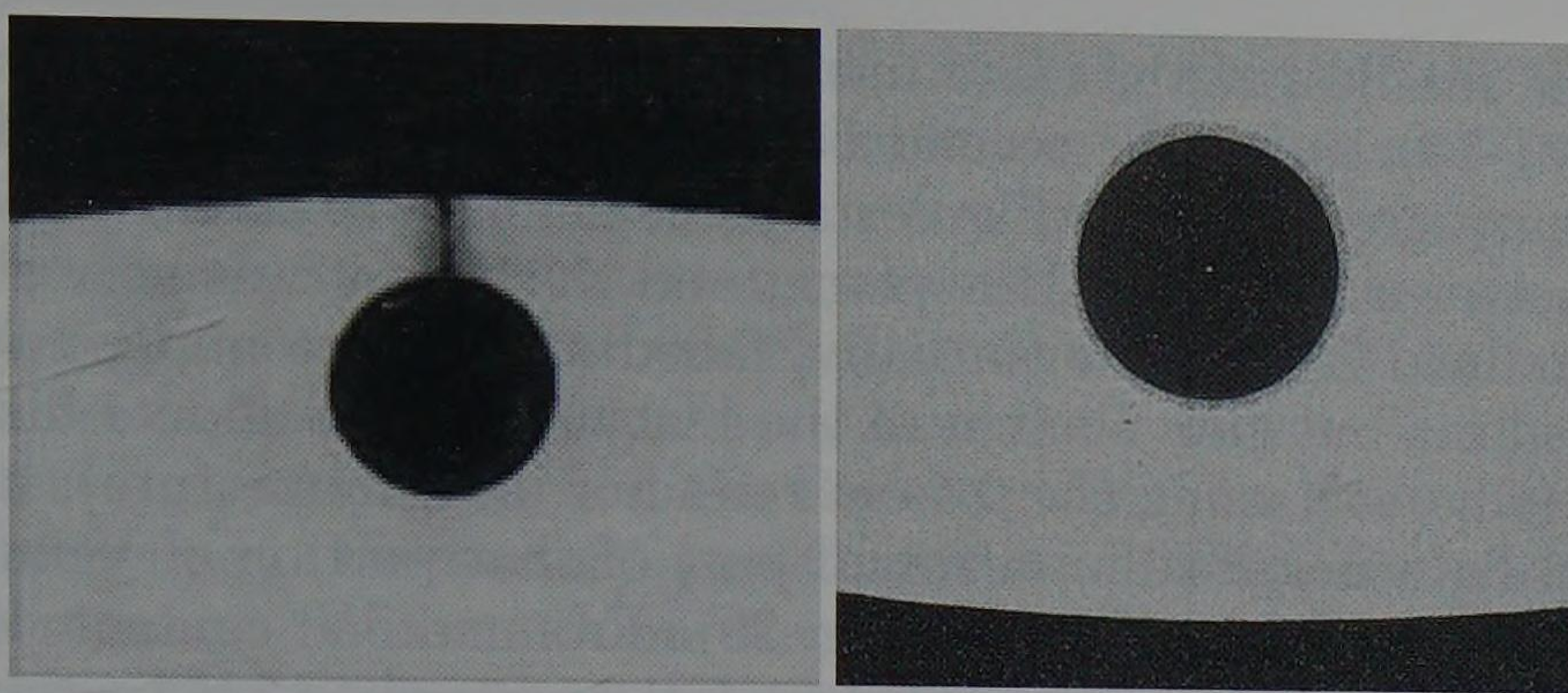

Figure 19. Left: Hirst's drawing of the black drop (after Lomb, 2004: 18). Right: Hirst's ring of dull red light (after Russell, 1892: Plate XV).

planetary observer (Greig-Smith, 1916: 5), and he was adamant that he had indeed seen the black drop: "... I am convinced that my observations, short though they were, have not deceived me. I was thoroughly prepared and on the look out for the phenomenon at egress, and I have not the slightest doubt that anyone, no matter how inexperienced in observation, using similar optical instruments, would undoubtedly have observed what I did." (Hirst, 1883: 72).

DuFaur (1892) recorded the third contact, but the poor condition of his eyepieces prevented him from looking for any anomalous phenomena – although he noted the absence of the black drop at this time. About fifteen minutes after third contact, Vessey (1883: 66–67) noticed that the disk of Venus was "... slightly reddish or copper coloured, like the Moon in eclipse, the sky adjoining being intensely black with the suspicion of a greenish tinge, contrasting with the colour of the planet. Repeated comparisons were made between the planet and sky to verify this ..." A further fifteen minutes later fourth contact took place.

There were two Sydney Observatory transit stations to the south of Woodford, and one of these was set up in a park in the city of Goulburn (longitude = 09h 58m 50.67s E; latitude = 34° 45′ 12.″6 S), about 200 km by rail SW of Sydney. Members of the transit party were Russell's friend and colleague from the University of Sydney, Professor Archibald Liversidge, Captain Francis Hixson, President of the Marine Board, Captain A. Onslow, an M.P., the respected scientific instrument-maker, Angelo Tornaghi and a carpenter (see Fig. 12). Telescopes at their disposal were 15.2-cm (6-in), 9.5-cm (3.75-in) and 8.3-cm (3-25-in) equatorially-mounted refractors, supplemented by a Poole chronometer.

Using the smallest of the three telescopes (at full aperture), Liversidge (1883: 74–75) timed the second contact, and shortly afterwards "... a faint hazy grey filament like a streak of smoke was momentarily observed between the edge of the planet and the Sun; it was very obscure and ill-defined ... [and eventually] faded away quite imperceptibly." He looked for but saw no sign of the black drop. At about this time, Onslow (who was using the 9.5-cm refractor, at full aperture), noticed an arc of light begin to form round part of that portion of Venus that was still off the Sun's disk (see Fig. 20). From second contact, Hixson (1883) used the 15.2-cm refractor at full aperture to photograph the transit, assisted for part of the time by Tornaghi.

The two egress contacts were observed, and timed, by all of the observers. Hixson did not note any anomalous features, but Liversidge, Onslow and Tornaghi did. Liversidge (1883: 75) reports that about fifteen minutes before third contact he first noticed that Venus "... appeared spheroidal, and not as a disk merely; it appeared illuminated on the inner side in the direction of the Sun's diameter, and this illumination shaded off on the side of the planet, but at the portion nearest the Sun's limb it appeared quite black and opague." About four minutes after third contact "... the planet was just beginning to pass off the Sun's limb, and it looked somewhat as if it were pushing that portion of the Sun's limb before it, for the solar limb appeared to be raised up into two processes, one on each side ..." (*ibid.*; see the two left hand drawings in Fig. 20, right).

In contrast, soon after third contact Onslow witnessed a re-appearance of the arc of light noted at ingress (see Fig. 20), and about this same time Tornaghi "... saw the halo, and it was best when the planet was half off the Sun: the outside had a greenish colour with red in it, and appeared as if formed by flames issuing from the planet all round,

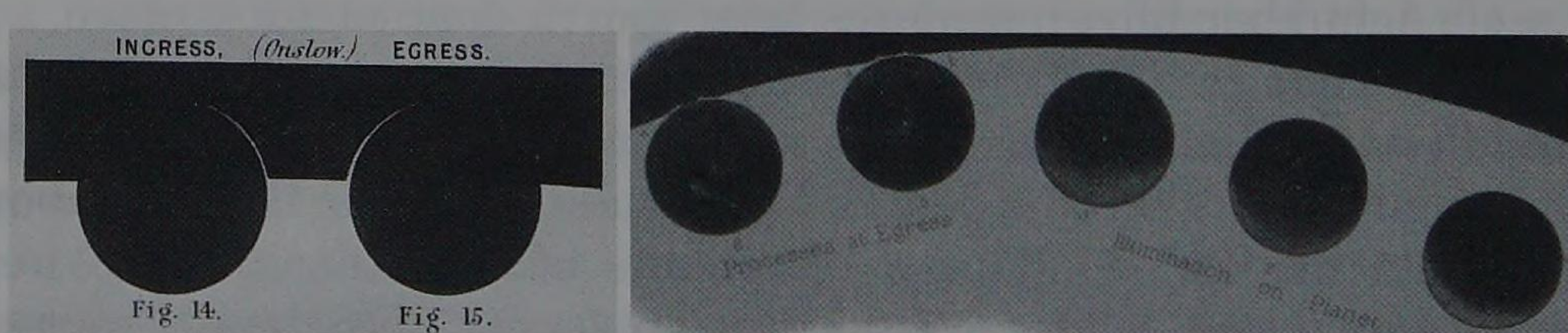

Figure 20. Left: Onslow's drawings of the arc of light at ingress and egress (after Onslow & Tornaghi, 1883: Plate II). Right: Liversidge's drawings of the egress (adapted from Russell, 1892: Plate XXII).

and densest at the planet. The halo round the part on the Sun was different, but quite distinct and unmistakable." (Onslow and Tornaghi, 1883: 77). Tornaghi used the 9.5-cm refractor for these observations.

The fourth Sydney Observatory transit station was in a park at Eden (longitude = 09h 59m 36.06s E; latitude = 37° 03′ 47″ S), on the far south coast of New South Wales very near the Victorian border, where the observing party comprised the Reverend William Scott, former director of Sydney Observatory (see Orchiston, 1998b), the noted amateur astronomer, William John Macdonnell (Orchiston, 2001d), John L. Watkins, Mr Sharkey (a photographer) and a carpenter (see Fig. 12). Their equipment included an 18.4-cm (7.25-in) Merz refractor, 10.8-cm (4.25-in) and 8.3-cm (3.25-in) refractors, a 5.1-cm (2-in) portable transit telescope, a clock and three chronometers (Scott, 1883: 79). Fig. 21 shows the transit station and the two smaller telescopes.

Figure 21. The Eden transit station (after Russell, 1892: Plate XXXVI).

During ingress, Scott used the Merz telescope stopped down to just 5.1-cm (2 inches) and "... soon became convinced that all we had heard and read respecting the apparent elongation of the planet's disk, and formation of what has been described as the "drop," was a delusion." (Scott, 1883: 81). Several minutes before second contact, he reported that he "... could see clearly the whole of the planet's outline; in fact, it presented exactly such an appearance as might have

been expected from a planet possessing an atmosphere [cf. Fig. 18]. Whilst the direct light of a portion of the Sun was shut out by the intervention of the planet, a sufficient portion of the light reached the eye by refraction, through the atmosphere, to render the whole outline visible." (Scott, 1883: 81–82). He then used a double-wire position micrometer to measure the diameter of Venus, and timed the instant of second contact.

Macdonnell used the 10.8-cm Cooke refractor at full aperture for his observations. Like Scott he timed the first and second contacts, but about half way between the two he noticed that "... a shadowy nebulous ring seemed to envelop *Venus* on the preceding side: it was of lighter tint than the planet, but was decidedly perceptible, and appeared to be about a quarter or a fifth of Venus's diameter in width (Plate IV, fig. 7)." (Macdonnell, 1883: 84). Macdonnell's drawing of this feature is reproduced here in Fig. 22. Soon afterwards, "... the whole outline of the planet was distinctly visible in the telescope, the shadowy envelope surrounding it very plainly." (*ibid.*).

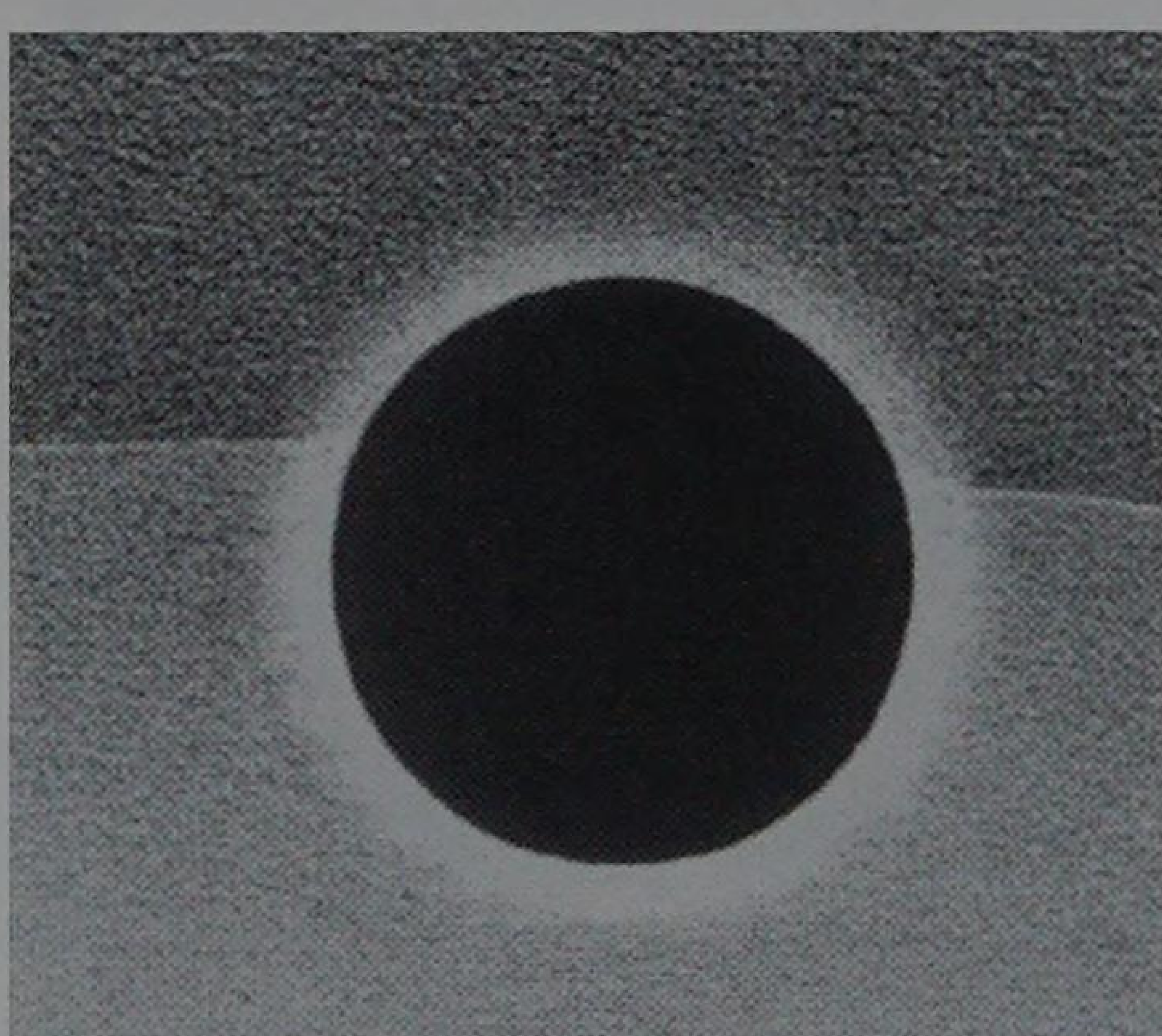

Figure 22. 'Halo' observed by Macdonnell at ingress (after Russell, 1892: Plate XVIII).

Watkins was observing with the 8.3-cm refractor, stopped down to 3.8-cm (1.5 inches), and with some difficulty timed the second contact. He noted that prior to this event "I did not see any halo; but as I did not observe the planet with the intention of noting phenomena other than the times of contact, a faint halo might well have been observed by others without being noticed by me." (Watkins, 1892).

Immediately after second contact none of the observers saw any sign of the black drop, and it was at this time that Scott installed a 7.6-cm (3 inch) diaphragm on the large Merz telescope and that he and Sharkey began taking a series of photographs of Venus on the Sun's disk. Unfortunately, clouds greatly hampered their efforts, and

although they succeeded in taking fifty photographs, Scott (1883: 83) felt that very few of these would be of value. Macdonnell (1883: 84) remained at his telescope throughout this period, and during a number of momentary glimpses of the Sun noticed that the "shadowy envelope" had completely disappeared.

Heavy black clouds prevented all observers from seeing the egress contacts, and Scott (1883: 83) came away from Eden far from impressed: "On the whole the expedition ... has not been a success, and ... Eden, though a beautiful spot, and in many respects a most desirable place to inhabit, is about the worst place for astronomical observations that I ever visited."

Colonial Observatories. Melbourne Observatory.

Melbourne Observatory (Fig. 23) opened in 1863 at the head of Port Phillip Bay, and had evolved out of the earlier Williamstown and Flagstaff Observatories. It was Australia's premier professional observatory during the nineteenth century (see Haynes et al., 1996; Perdrix, 1961). Like its Sydney counterpart, it was concerned with far more than just astronomy, but from 1869 one of its main claims to fame was the Great Melbourne Telescope, the largest equatorially-mounted telescope in the world at that time (Gascoigne, 1996; Perdrix, 1992).

Under the guidance of its charismatic founding director, Robert Ellery (Gascoigne, 1992; see Fig. 11), Melbourne Observatory organised an ambitious transit program, but with four stations (the same as Sydney Observatory), and obtained Victorian Government funding in order to properly equip these. The primary transit station was Melbourne Observatory itself (longitude = 09h 39m 53.83s E of Greenwich and latitude = 37° 49′ 53″.4 S), where Ellery, John White (the First Assistant), Joseph Turner (the Great Melbourne Telescope Chief Observer) and W.C. Kernot from the University of Melbourne were the principal observers, ably assisted by Messrs. Bennett, Buchanan, W.M. Cook, F. Henderson, Josephs, W.F. Tait and J. Wilson. Ellery and White used a new Troughton and Simms 20.3-cm (8-in) refractor for visual monitoring (see Fig. 24); White also observed part of the transit with a 7-cm (2.75-in) altazimuth refractor; Kernot oversaw the photographic program of the distinctive 10.2-cm (4-in) Dallmeyer photoheliograph (Clark & Orchiston, 2004); and Turner and his assistants planned to take photographs with the Great Melbourne Telescope.

The morning of 9 December dawned overcast, with thunder, lightning and occasional rain, but gaps in the clouds appeared just before

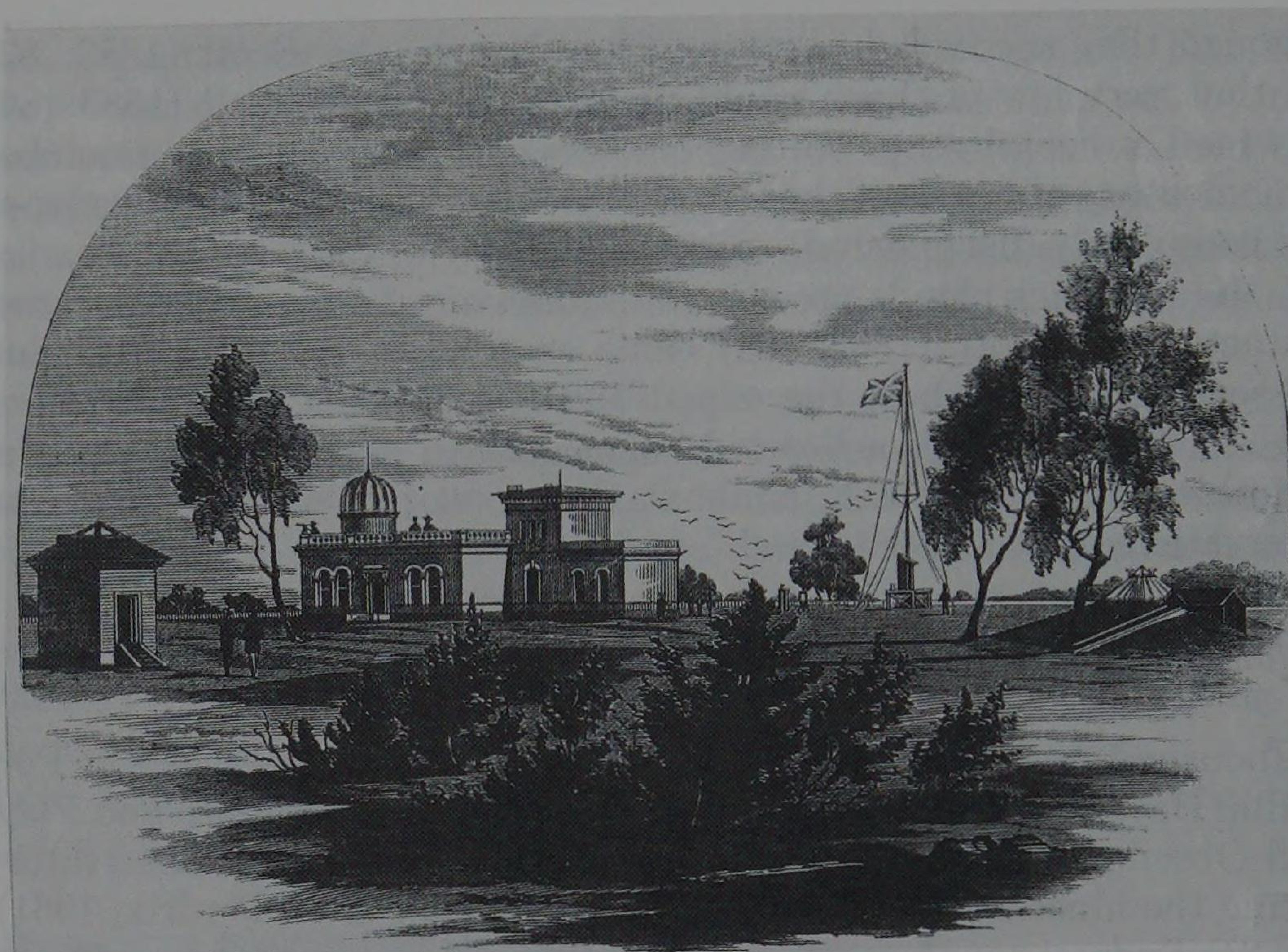

Figure 23. Melbourne Observatory in 1863 (Orchiston Collection).

second contact, which was observed by Ellery and White with the two refractors (both operating at full aperture). At the time, Ellery noted: "The complete disk of *Venus* plainly visible, that portion beyond the Sun's limb quite distinct and *margined by a thin edge of light* (Plate I, fig. 1). As the time of Internal Contact approached (about 1½ minutes before), the cusps of the Sun's limb appeared to bulge out and embrace *Venus* and to meet around it (fig. 2)." (Ellery, 1883: 33). The two diagrams that Ellery refers to have been reproduced here in Fig. 25. This bulging of the Sun's limb continued as the time of second contact approached. Second contact was timed with precision, and there was no sign of the black drop. Instead, a "Chinaman's Cap" was very faintly seen for an instant; Ellery describes this feature: "... it is like a very obtuse triangle with its broad base towards the Sun's limb, whilst its apex touches *Venus*, the two similar sides being curved towards the base and towards each other (fig. 3)." This feature is also shown in Fig. 25. Immediately after this, "... a streak of light was occasionally seen to glimmer clear between the planet and the Sun's limb; this soon

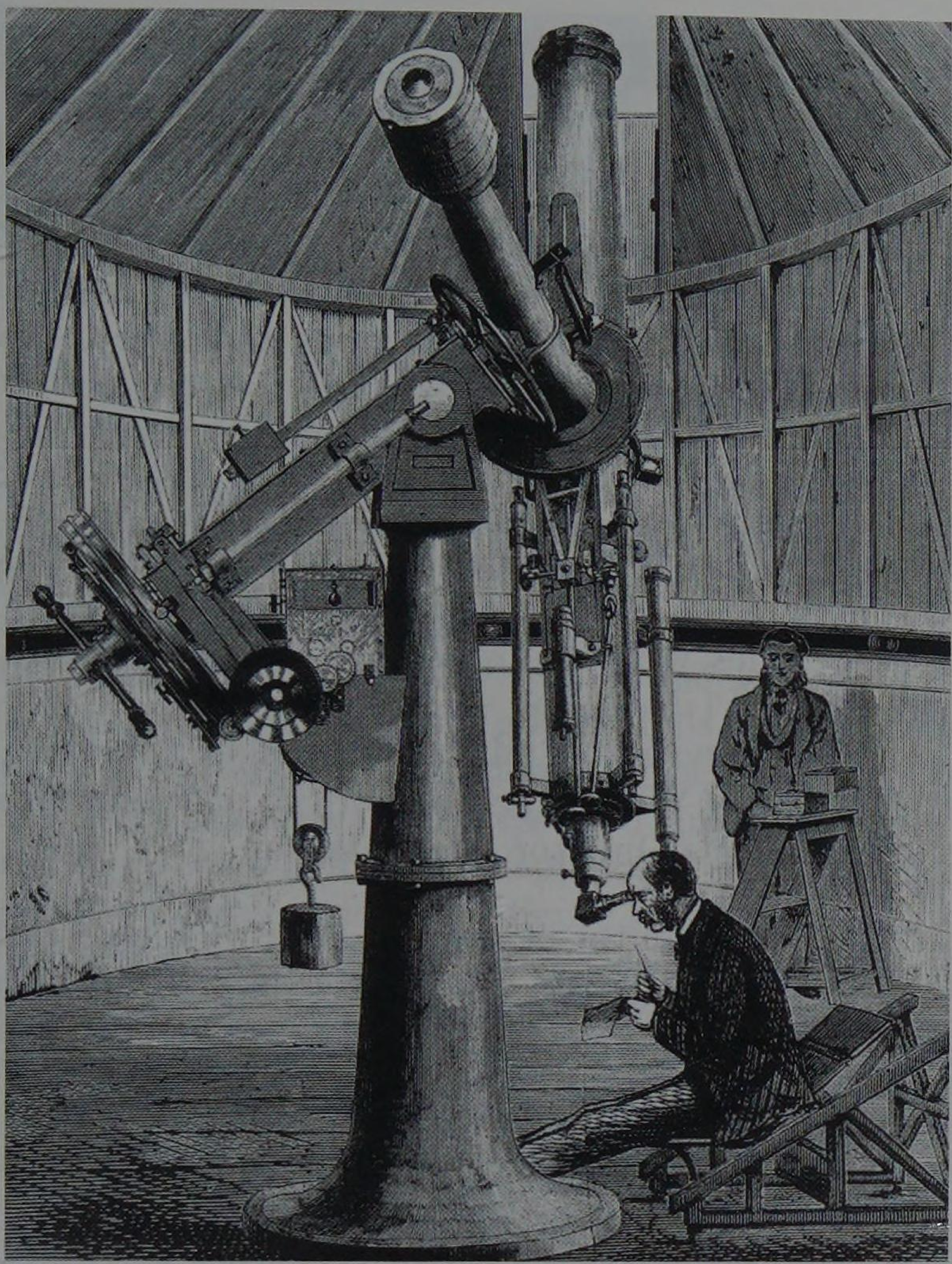

Figure 24. Observing the transit with the 20.3-cm Troughton & Simms refractor at Melbourne Observatory (Orchiston Collection).

gave to the fourth appearance, when a broad band, as if of thin smoke, occupied the space between *Venus* and the Sun's limb (fig. 4) [again, see Fig. 25]. This gradually gathered up, as it were, till in became like a very thin thread, which was now and then invisible ... it appeared sharper and thinner at last, and then suddenly disappeared ..." (Ellery, 1883: 33–34). Ellery specifically mentioned that none of the afore-mentioned features was very marked, and that in all probability they would not have been seen at all in a smaller telescope or by an inexperienced observer (Ellery, 1883: 34). He also commented on the

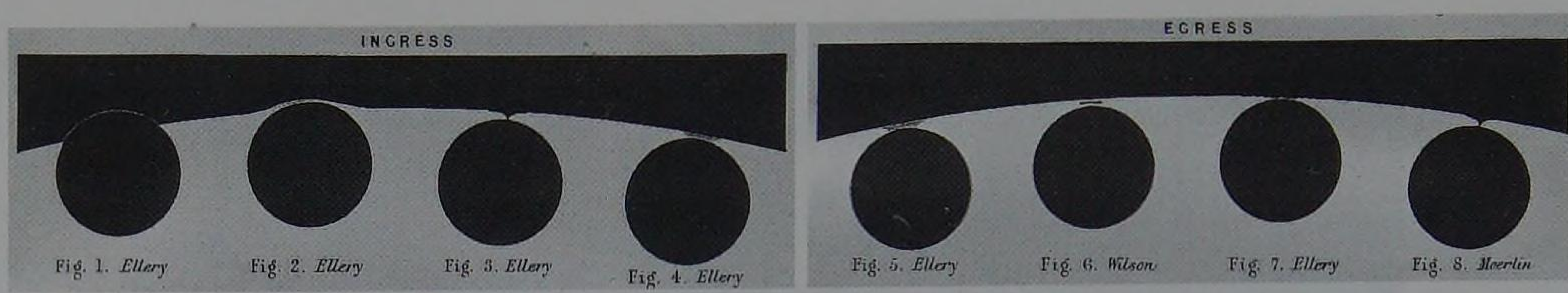

Figure 25. Ellery's drawings during ingress (after Ellery, 1883: Plate I) and egress (observations by Ellery, Moerlin and Wilson, after Ellery, 1883: Plate I).

slow motion of Venus during the ingress phase, which meant that "... it was impossible to assign the time of the true Internal Contact to within two or three seconds of time with any certainty, even when the edges of the two bodies were almost perfectly quiescent and as sharp as two disks of metal." (*ibid.*).

Using a telescope with a significantly smaller aperture, it is perhaps not surprising that White's account of the ingress phase does not *exactly* mirror that of his Director. He states:

> "At about three minutes before the time of First Internal Contact ... [when] *Venus* was nearly on the Sun's limb, the part off the Sun was partly embraced by two bright horns stretching out from the surface of the Sun ... *Venus* appeared to be attached to the Sun by a very broad ligament nearly as black as the planet itself ... At the phase marked "Chinaman's Cap" the ligament narrowed very much on the side of *Venus*, the broad part still attaching to the Sun's limb. At the phase marked "bright streak of light" a bright arc of light appeared between the broad part of the "cap" and the Sun's limb ..." (White, 1883: 40).

The Sun was then hidden by clouds for seventeen seconds, and when it reappeared White noticed that the "cap" was gone.

Soon after second contact, Ellery and White used the Troughton and Simms telescope to begin a series of twelve micrometric measures of the diameter of Venus, and these were followed by twenty measurements of the distance of Venus from the limb of the Sun. Ellery then mounted "A careful scrutiny for any appearance indicating an atmosphere about *Venus* ... but nothing definite was observed ... [nor any] signs whatever of a satellite of *Venus* ..." (Ellery, 1883: 35). It was at about this stage of the transit that Ellery (1883: 36) first noticed that "The outer portion of the disk of *Venus* was coloured a very deep blue

(indigo), and the colour extended from the edge of the disk towards the centre about a quarter of the diameter of Venus." This was not a personal idiosyncrasy for White and two other observers also noted this distinctive colour.

A little over an hour before third contact, Ellery and White began another micrometric program, this time taking sixteen measurements of the diameter of Venus. At third contact Ellery first noticed a faint "smoky junction" between the limbs of Venus and the Sun, which with time varied in width and intensity, partly because observing conditions had deteriorated somewhat since the ingress phase (see Fig. 25). This made it difficult to accurately determine when third contact occurred. White followed up with further measures of the distance of Venus from the Sun's limb, and then Ellery and White timed the final the egress contact with considerable difficulty as by this time "... the Sun's edge was much disturbed, and the indentations from boiling were not distinguishable from the later appearances of the limb of Venus." (*ibid.*).

White's description of the egress also differs slightly from that provided by Ellery. As third contact approached, White (1883: 40–41) noticed that "... a dusky triangular figure was thrown off from *Venus*, the apex being towards the planet and the base towards the nearest part of the Sun's limb. The "cap" in this instance did not appear to be nearly as black as at the First Internal Contact ... the cap [then] came into contact with the Sun's limb, at the same time the apex had continually increased in breadth." He then proceeded to the 20.3-cm refractor to work with Ellery, and did not independently record the fourth contact.

While Ellery and White were immersed in their visual and micrometric observations, Kernot and his assistants, Cook, Henderson, Tait and Wilson (presumed to be engineering students), were preoccupied with the photoheliograph (Fig. 26). In order to record the ingress and egress contacts, a Janssen apparatus (see Launay, 2004) was attached to this telescope. This novel device was constructed by Dallmeyer to a design provided by de la Rue (1874), and could take twenty photographs in quick succession on a 15.2-cm (6-in) diameter circular glass plate – infinitely much faster than could be achieved with the rather cumbersome standard wet plate holders (Clark and Orchiston, 2004). In all, Kernot's team succeeded in obtaining about 180 images of the four contacts (White, 1875), indicating that at least nine different plates were exposed. The photoheliograph was also busy between the ingress and egress phases, when the standard plate-holder was used and thirty-seven photographs of Venus on the Sun's disk were obtained (*ibid.*).

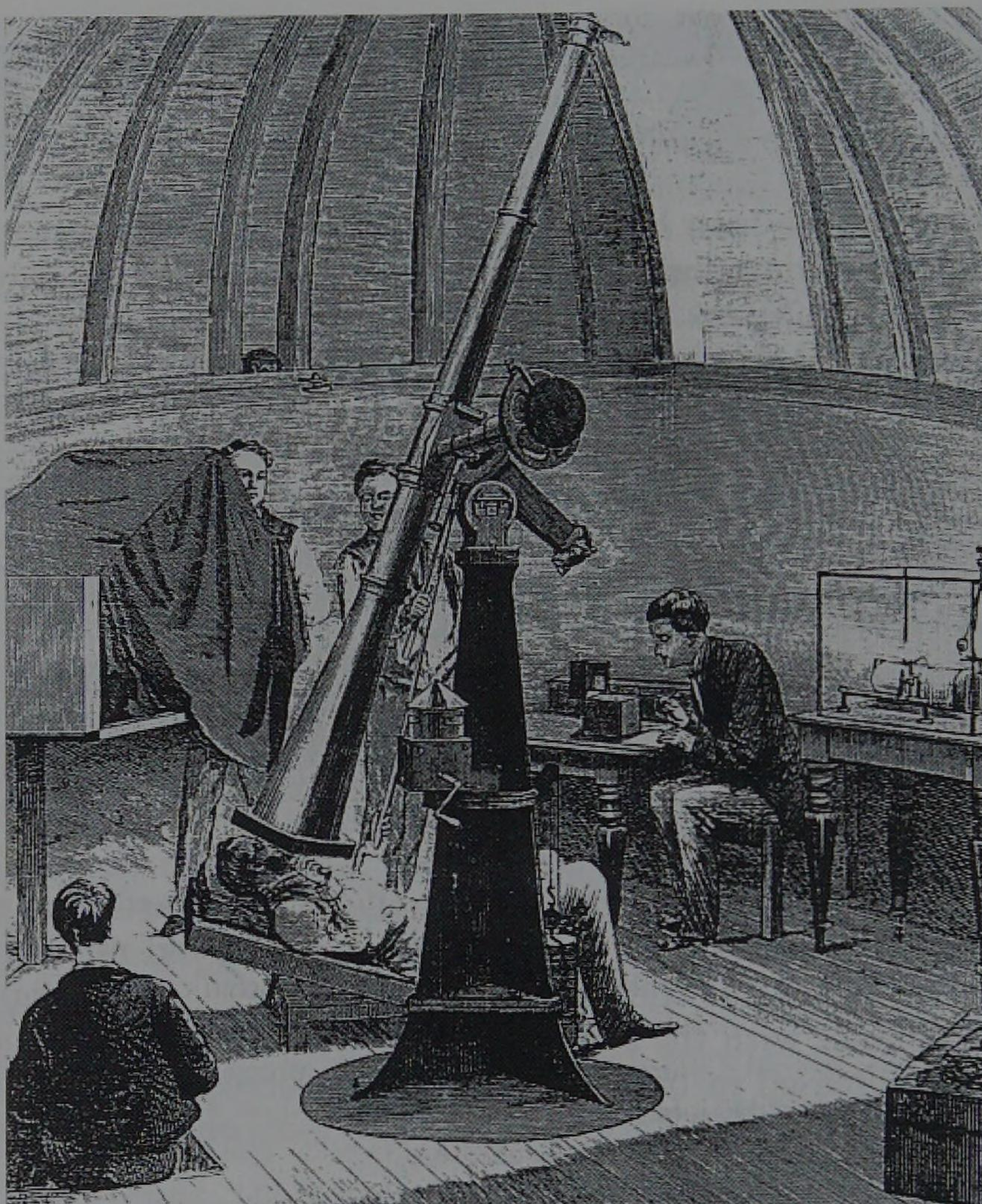

Figure 26. Observing the transit with the Melbourne Observatory Dallmeyer photoheliograph (Orchiston Collection).

The other photographic team of Turner, Bennett and Josephs was at the Great Melbourne Telescope (Fig. 27), and throughout the transit "... succeeded in producing most excellent results ..." (The transit of Venus, 1874d). The only photographic 'hiccup' occurred at the start of the ingress phase when the telescope "... through its not being got into position in time for the first contact, no picture was taken by it of that portion of the contact." (*ibid.*).

One of the three Melbourne Observatory country stations was established at Mornington, on Port Phillip Bay to the south of Melbourne (at a longitude of 09h 40m 08.73s E and a latitude of 38° 13′ 54″ S). Pro-

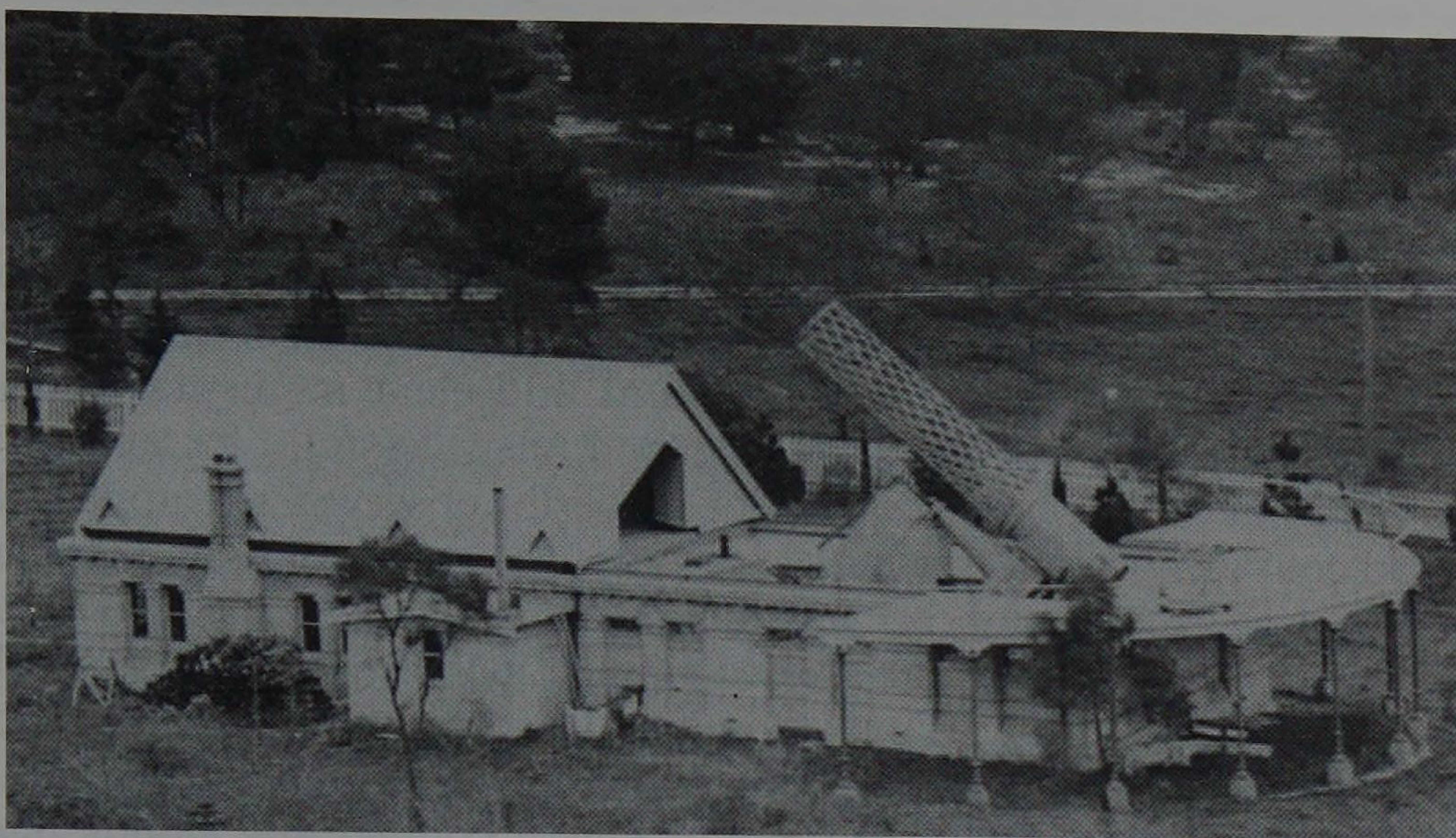

Figure 27. The Great Melbourne Telescope (Courtesy: RAS Archives, London).

fessor W.P. Wilson from the University of Melbourne was the principal observer there, aided by two students, Cook and Oliver (The transit of Venus, 1874d), and they used an 11.4-cm (4.5-in) equatorially-mounted Troughton and Simms refractor (at full aperture) and a chronometer. Dense clouds with thunder and lightning prevented observation of the first contact, but about five minutes before second contract they thinned, the definition was "very good", and Wilson (1883: 42) noticed "... an appearance I do not recollect having seen described. The circle of the dark body of Venus was continued and complete outside the edge of the Sun, marked out by a luminous arc." (cf. Fig. 18). Wilson was quite certain about this, and that "... it was not a mere mental continuation of the circle." (*ibid.*). From this time, passing clouds hampered observations, until near the time of third contact when the sky cleared, although the definition was poor. At this time, Wilson noted that "*Venus* did not look round, but as one might imagine a spherical balloon not quite blown up." He timed the third and fourth contacts as best he could and between these two events again noticed "... the continuation of the circle of *Venus* outside the limb of the Sun, but the appearance was not nearly so definite as at ingress." (Wilson, 1883: 43).

The Second Assistant at Melbourne Observatory, C. Moerlin, was responsible for the Sandhurst transit station (longitude = 09h 37m 12.8s

E; latitude = 36° 48′ 16″.9 S), at View Hill on the outskirts of present-day Bendigo, where he was assisted by A. Black (a surveyor) and Messrs McLean and Pirani (The transit of Venus, 1874d). They had access to the Observatory's 16.5-cm (6.5-in) equatorial-mounted Ertel refractor and a chronometer. Heavy clouds prevented any observations of the ingress contacts, but at various times after second contact the transit was visible through passing clouds and at odd clear moments, and it was then that Moerlin (1883: 44) searched unsuccessfully for any sign of a Venusian atmosphere or satellite. Moerlin observed the approach of third contact through passing clouds, and the streak of light between Venus and the Sun's limb became smaller and smaller "... and then all at once a sort of triangular-shaped connection between the two took place ... the base of the triangle being on the Sun's limb and the apex on the planet ...". (Moerlin, 1883: 45). Moerlin's drawing of this is reproduced in Fig. 25. By the time of fourth contact the clouds had moved in again, preventing any further observations.

The third Melbourne Observatory country transit station was at longitude 09h 44m 53.33s E and latitude 36° 28′ 04″ S, in the north-eastern Victorian town of Glenrowan), where A.C. Allan (Inspector of Surveys) and James Gilbert (Fourth Assistant at Melbourne Observatory) made use of the Observatory's 11.4-cm (4.5-in) equatorially-mounted Cooke refractor (at full aperture), ably assisted by a Mr Paynter (Baracchi, 1914: 363; The transit of Venus, 1874d). On the morning of the transit clouds prevented any observation of the first contact, but they thinned soon after, and at about 23h 32m 03s about half the planet was on the Sun's disk when Gilbert (1883: 46) noticed "... that the apparent N.W. limb of *Venus* (the part nearest the centre of the Sun) suddenly became illuminated, and remained so till $23^h 50^m 35^s$, when the illumination just as suddenly disappeared, the planet resuming its dark colour ..." Almost eight minutes later, Gilbert (*ibid.*) reported that "... the continuation of *Venus's* limb was visible outside the Sun's edge, and luminous, the margin being quite distinct where the luminosity was densest ... At 23^h $58^m 53^s$ the ligament commenced to form, and the luminous halo above referred to disappeared..." The ligament persisted, but at $00^h 00^m 42^s.5$ it suddenly "snapped". Shortly after this clouds intervened, and when Gilbert next viewed the Sun the second contact was long past. At $01^h 58^m 34^s$ he "... first noticed that a portion of Venus appeared of a violet colour extending from the limb inwards, leaving a dark central body almost black, the diameter of the violet ring being about a quarter of the planet." (Gilbert, 1883:

46–47). Soon after the sky clouded over, and eventually light rain fell, preventing any further observations of the transit.

Carrying out independent observations at the Glenrowan station was an experienced amateur astronomer named Ebeneler Reginald Morris (see Orchiston, 1987: 69–70), who used his own 21.6-cm (8.5-in) Browning-With reflector. Morris provides the following account:

> "*Venus* first seen on Sun's limb at 23^h32^m (Melbourne Mean Time) (Plate I. fig. 12). Outline of planet plainly visible outside the Sun's disk. At 23^h37^m observed the southern cusp to be much sharper than the northern one. A ligament was first noticed at $23^h57^m17^s$ (fig. 9). This afterwards became more distinct, and was not so dark as the planet itself. The ligament gradually lessened in width, and at 00^h $00^m45.8^s$ (fig. 11) was so narrow and filmy that it was scarcely perceptible – before the rupture was observed clouds obscured the Sun. The ligament seemed in fact to melt away gradually. At 0^h1^m 11.5^s the planet was clear of the Sun's limb – now I first noticed a faint whitish appearance on the eastern portion of the planet ... After $2^h30^m$the sky was completely overcast." (cited in Gilbert, 1883: 47).

Soon after the transit, Ellery (1874) sent Airy a long report, the first part of which summarised the overall Melbourne Observatory program:

> "We had very fair success with the Transit of Venus & observed internal contacts at ingress & egress, the first under exceptionally favourable circumstances, one or other of the phases was also observed at each of our three subsidiary stations. The times were somewhat later for ingress & earlier for egress than those in the Ephemeris ... Our photographic work of the Transit I fear is not a great success, however we obtained a lot of photographs ... both with Janssen & other plate holder. I have sent sample prints to Mr de la Rue ...

Ellery's letter also reports briefly on other Australian transit observations and on those conducted by foreign parties based in New Zealand and its subantarctic waters.

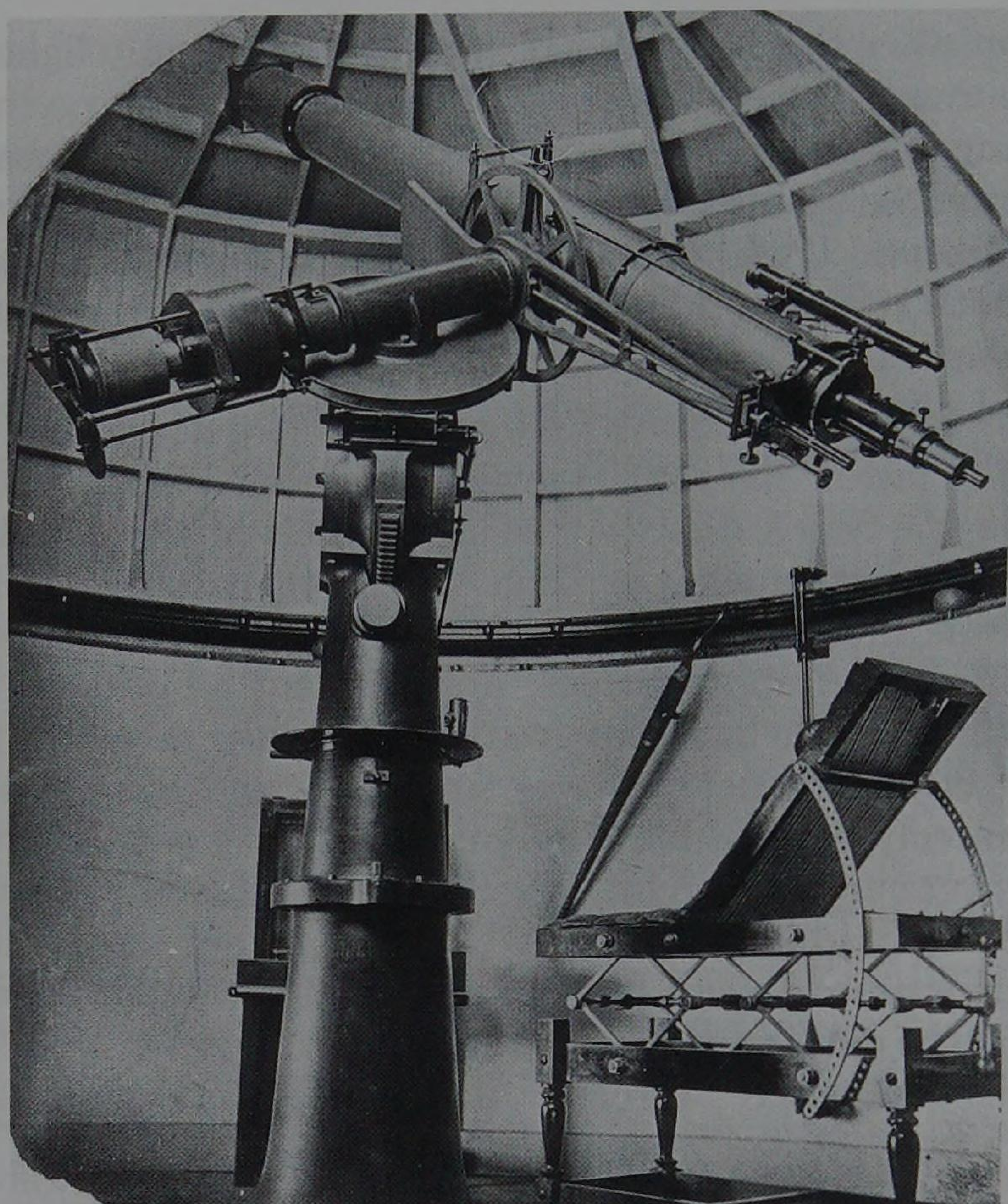

Figure 28. The Adelaide Observatory's 20.3-cm Cooke refractor (Courtesy: State Library of South Australia, Adelaide; SLSA: B 12156).

Colonial Observatories. Adelaide Observatory.

Charles (later Sir Charles) Todd (Fig. 11), the charismatic Director of the Adelaide Observatory (see Edwards, 1993), arranged to conduct visual, micrometric and photographic observations of the transit from Adelaide Observatory (longitude = 09h 14m 21.3s E and latitude = 34° 55′ 34″ S), in the heart of Adelaide (the capital of South Australia). Previously, he had used the transit to lever the healthy sum of £800 out of the South Australian Government (Todd, 1873) for the purchase of a new 20.3-cm (8-in) Cooke refractor (Baracchi, 1914; see Fig. 28). For the transit, this was stopped down to 10.2-cm (4 inches). Like Russell, Todd (1874) asked Airy for advice on the best observing pro-

cedure during the transit, but unfortunately cloudy weather prevented any observations from being made until after the ingress contacts (see Edwards, 2004). Todd was then able to secure a series of micrometric measures of the distance of Venus from the limb of the Sun, but he did not regard the early ones as good, "... owing party to the disturbed condition of the atmosphere, and partly also to the want of practice, and uncomfortable position ..." In contrast, later measures, obtained as Venus approached the egress contacts, "... were taken with great care, and will, I trust, prove of some value." (Todd, 1883: 93). Meanwhile, Mr. Crawford (the Government photo-lithographer) secured a few photographs of the transit shortly after its mid point, but these showed a flattened oval image of Venus owning to poor seeing that prevailed at that time.

As third contact approached, Todd watched for the black drop, but to no avail: "With regard to the "black drop", of which so much has been written, I wish I had never heard of it, as looking eagerly for its appearance and not seeing what I expected was certainly calculated to bias my judgement as to the precise instant of Internal Contact ... I saw nothing like the representations given of the "black drop." There was, I thought, a slight oscillating movement (of course only apparent) of the planet to and from the limb which made it excessively difficult to fix positively the exact instant of Contact ..." (Todd, 1883: 94). After third contact, Todd was surprised to see that portion of Venus already off the Sun "... remain distinctly visible and sharply defined ... The planet – that is, the segment off the Sun's disk – appeared to be surrounded and to be seen through, as though enveloped in a faintly luminous nebulous haze of a purplish hue inclining to violet on the planet towards the Sun." (Todd, 1883: 95). Todd's assistant, Alexander Ringwood, was called to the telescope and also saw the "nebulous haze, which he described as "... a faint light, the colour of which was of a faint violet, pink, or red, mixed with bluish tint ..." (*ibid.*). Favourable weather eventually allowed Todd to obtain a time for the final egress contact.

Independent Observers. Armidale.
A.W. Belfield and Archibald J. Park observed from the inland northern New South Wales city of Armidale, using an 11.4-cm (4.5-in) Cooke refractor at full aperture, and both recorded interesting features of Venus during the ingress phase. Belfield (1883: 85; my italics) wrote: "The illumination of the following limb of the planet at ingress seemed to be equal in breadth all round, and was bright enough to give an appear-

ance of elongation of the part of the planet not on the Sun's disk. It seemed to be outside the limb, which was quite distinct. Its breadth I see has been estimated at 1″ [by Wright; see below]; I should have thought it was nearer 2″ when Venus was two-thirds on the Sun's disk, *but I have no experience in making measurements of the kind.* I saw nothing like margin or shading round the part of the planet on the Sun's disk." Park (1883) also noticed this distinctive illumination, and their drawings of it are comparable with the two right hand images shown in Fig. 18. To Belfield and Park, Venus appeared black in the centre, grading to "deepest Prussian blue" at the limb. Belfield (1883: 86) notes that "The colour was very vivid during the earlier part of the Transit, when the air was very good ..."

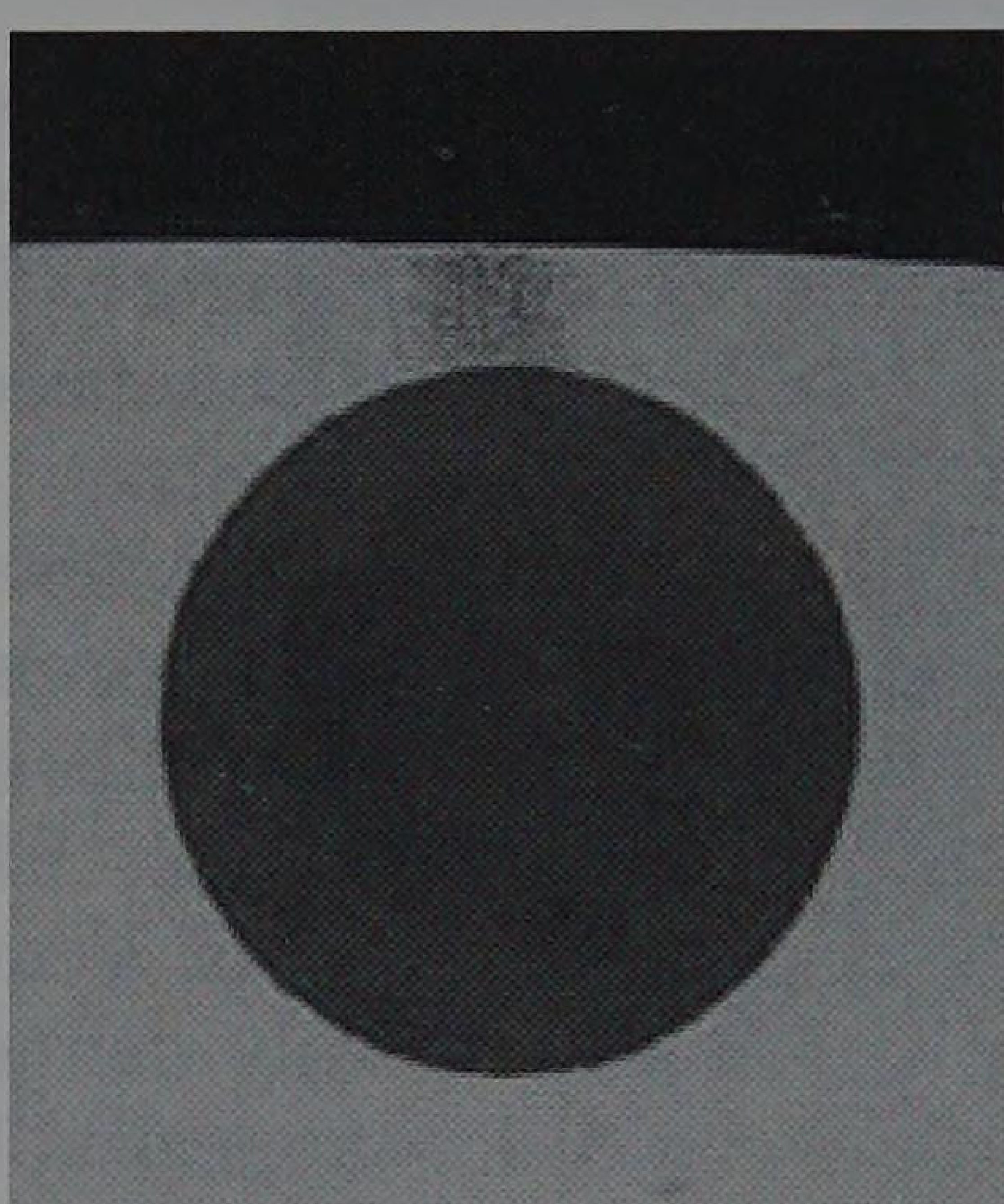

Figure 29. The 'tremulous shading' noted by A.H. Belfield; in its original version, this drawing also depicted the intense blue colour of Venus, commented on by both Belfield and Park (after Russell, 1892: Plate IX).

Belfield and Park (1892: 42) state that around the time of second contact they did not see any sign of the black drop, but they did note "... a faint tremulous shading ... between the edge of the planet and the limb of the sun ... which disappeared so gradually that it could not be said to have been obliterated at any particular instant." This "tremulous shading" is illustrated in Fig. 29, and despite their claims to the contrary does indeed bear some resemblance to the notorious black drop.

Distinct illumination of the limb of Venus already off the Sun was also a feature of the egress phase, and was noted by both Belfield and Park. However, on this occasion, "... the illumination was seen on only a part of the planet's disk ... at the intersection of the limbs of *Venus* and the Sun; on the Northern side of the planet (direct image) it was broader than at any part during ingress, but thinned off to nothing rapidly ... When *Venus* was about one-fourth off the Sun,

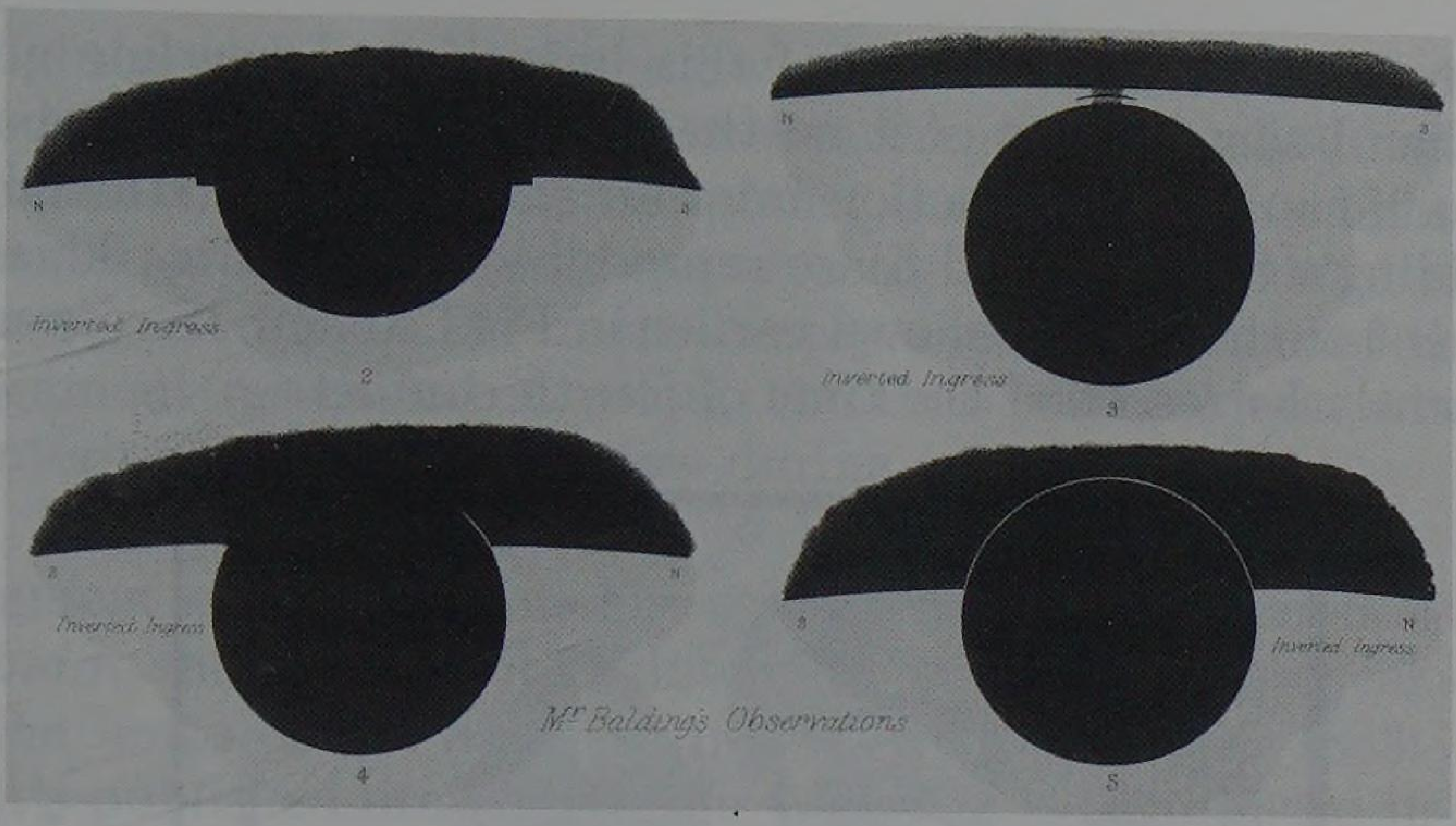

Figure 30. Bolding's drawing of ingress (top) and egress (bottom) features (adapted from Russell, 1892: Plate XXVIII).

the illumination extended over about one-third of the arc off the Sun; but as the planet's disk left the Sun, the extent of illumination did not increase accordingly, but was confined to about the same extent of outline as when first noticed." (Belfield, 1883: 86). Their drawings of this 'arc of light' mirror exactly the left hand image in Fig. 20. Once again there was no appearance of the black drop (Belfield and Park, 1892).

Independent Observers. Raymond Terrace.

The Police Magistrate at Raymond Terrace (near Newcastle) was H.J. Bolding, and he used a 7.6-cm (3-in) equatorially-mounted refractor (stopped down to 4.1-cm, or 1.625 inches) and a chronometer to observe the transit (Bolding, 1892: 40). A friend assisted throughout by noting contact times and recording descriptions of phenomena. Initially, the seeing was poor, and Bolding had trouble estimating the time of first contact. Immediately after second contact, Bolding noticed what he called "a parachute", and this feature is illustrated here in Fig. 30, top right.

By the time of the egress phase the seeing was excellent, and Bolding timed third contact without difficulty. About seven minutes later, at 4h. 7m., he saw "... a silvery line of light extending partly round the west side of the part of the planet off the sun (fig. 4); 30 seconds later I saw it all round the part of Venus as in fig. 5, and

I continued to see more or less of this beautiful silvery line until 4h. 11m., when I saw the last of it on the west side; it looked like a silver edging as if caused by refraction from an atmosphere." (Russell, 1892: 41). Bolding's figures 4 and 5 are reproduced here in Fig. 30, and are reminiscent of the images shown earlier in Figs 20 and 18 respectively. Subsequently he recorded the time of fourth contact.

Figure 31. John Tebbutt, as represented on the 1984 Australian $100 bank note (Orchiston Collection).

Independent Observers. Windsor.

Australia's foremost nineteenth century astronomer, John Tebbutt (Fig. 31; see Orchiston, 2001a, 2002, 2004a), observed the transit from Windsor, near Sydney, with an 11.4-cm (4.5-in) equatorially-mounted Cooke refractor (at full aperture) and a chronometer (see Tebbutt, 1875). With "remarkably favourable" weather, he was able to time all four contacts. After first contact he was surprised "... to find that the whole of that limb of *Venus* which had not entered on the Sun's disk was distinguishable, being marked off against the dark background of the sky by a margin of greyish light less than one second of arc in breadth. This halo gradually increased both in breadth and distinctness, till the planet's limb nearly coincided with that of the Sun. No halo or penumbra, however, surrounded that portion of the planet which was projected on the Sun." (Tebbutt, 1883: 90; cf. the 'halo' shown in Fig. 18). Although an experienced observer, Tebbutt (*ibid.*) writes of his "... excitement of the moment ..." with the imminence of second contact. Then,

> "A few seconds afterwards it was obvious that the apparent contact had taken place, the planet's limb being seen

> slightly within that of the Sun, but connected with it by a dusky ligament (fig. 10) whose breadth was about one-fourth the diameter of the planet ... It was of a lighter shade across the middle between the rounded ends of the cusps ... [and] The more deeply shaded portion of this ligament resembled in colour the limb of the Moon when entering the Earth's shadow during eclipse." (*ibid.*).

The ligament was then affected by a "... vibratory or tremulous motion ..." (*ibid.*), and resolved itself into "... several dusky streaks, parallel to the limbs of the Sun and planet ..." (Tebbutt, 1883: 90–91). Tebbutt's published drawing of this ligament is reproduced in Fig. 32, but differs considerably from his field sketch of the feature preserved in the Mitchell Library, which is much more reminiscent of a 'traditional' black drop.

Between second and third contacts, there was no indication of a halo round Venus, nor was there any sign of a satellite or of a white spot on the planet's disk.

Towards third contact, Tebbutt observed the same ligament phenomenon as at ingress, and about one and a half minutes later he

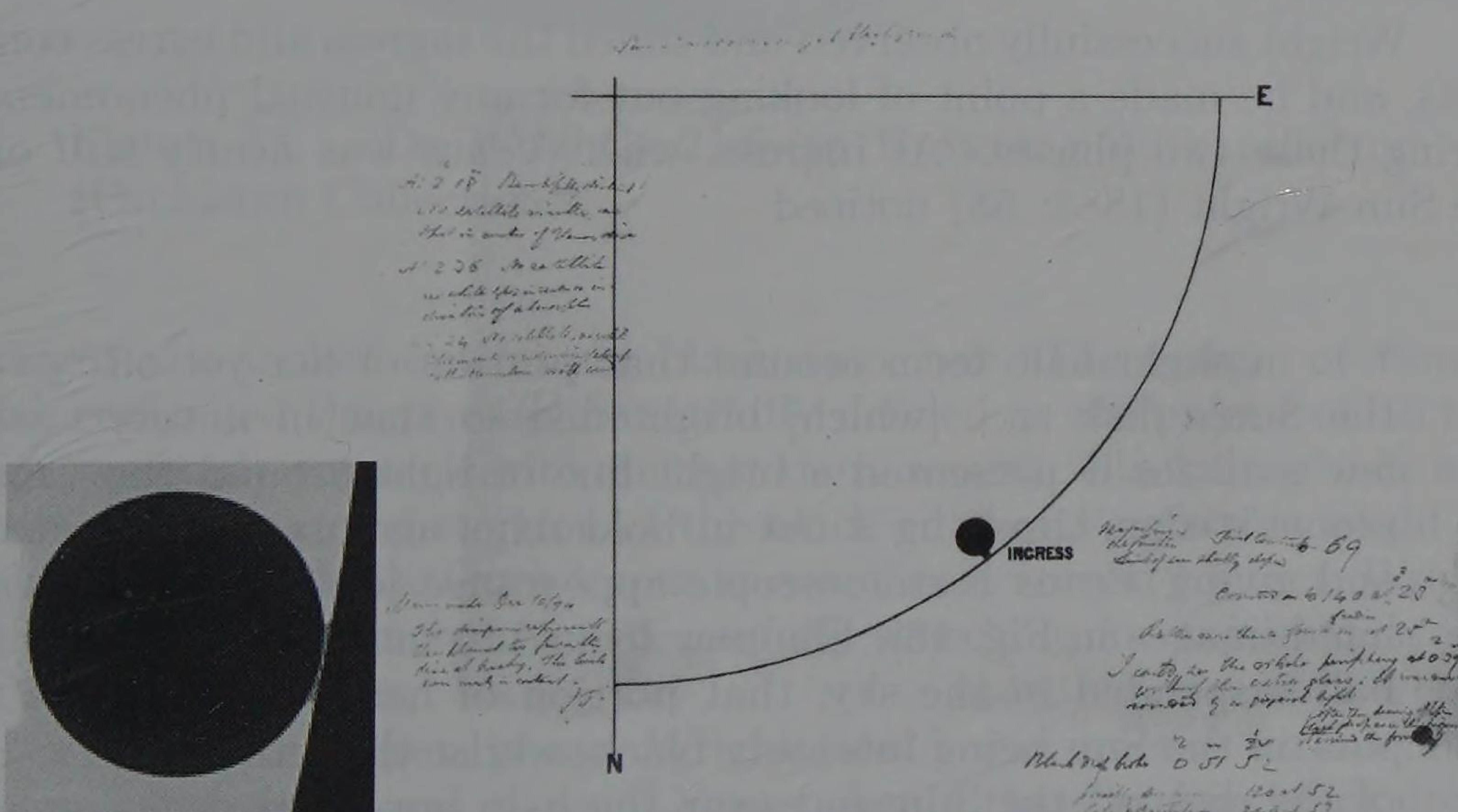

Figure 32. Tebbutt's drawings of the ingress 'ligament'. Left: the published version (after Tebbutt, 1883: Plate IV). Right: the original (Courtesy: The Mitchell Library, State Library of New South Wales, Sydney).

saw "... the limb of Venus faintly illuminated beyond the estimated place of the Sun's limb." (Tebbutt, 1883: 91). This halo gradually became more distinct and three and a half minutes later "... the grey light along the northern portion of the limb outside of the Sun's disk was beautifully distinct, but it was feeble along the southern portion." (Tebbutt, 1883: 92). It then began to fade, and was hardly visible ten minutes later. This egress feature is comparable to the one reported by Russell, Vessey and other observers (e.g. see the bottom right drawing in Fig. 30). Fourth contact was then timed with confidence, thus ending a successful observing program.

Independent Observers. Sydney.

Experienced amateur astronomer and medical practitioner, Dr Horatio G.A. Wright (see Fig. 12 and Hoare, 1976), observed the transit from his observatory in George Street, central Sydney (longitude = 10h 04m 48s E and latitude = 33° 52′ 04″ S), used a 21.6-cm (8.5-in) equatorially-mounted Browning-With reflector (Fig. 33) stopped down for part of the transit to just 13.3-cm (5.25 inches), a chronograph, and a chronometer that was calibrated to the sidereal clock at Sydney Observatory.

Wright successfully observed and timed the ingress and egress contacts, and he made a point of looking out for any unusual phenomena during these two phases. At ingress, when Venus was nearly half on the Sun Wright (1883: 58) noticed

> "... a slight halo form around that portion of her yet off the Sun's disk ... [which] brightened so that in a very few minutes it presented a bright line of light around the planet's edge, throwing it out in bold relief against the sky and giving *Venus* a stereoscopic appearance [cf. the right hand images in Fig. 18]. She now looked to me like a black ball suspended in the sky, that portion of her disk which was on the Sun being intensely black, whilst the remainder of the disk off the Sun and near the halo appeared decidedly lighter. The portion close to the halo was shaded with reddish brown colour. As she passed slowly on to the Sun's disk, the bright halo, at this time about 1″ in diameter, became very bright and was observed until *Venus* was fairly on the Sun."

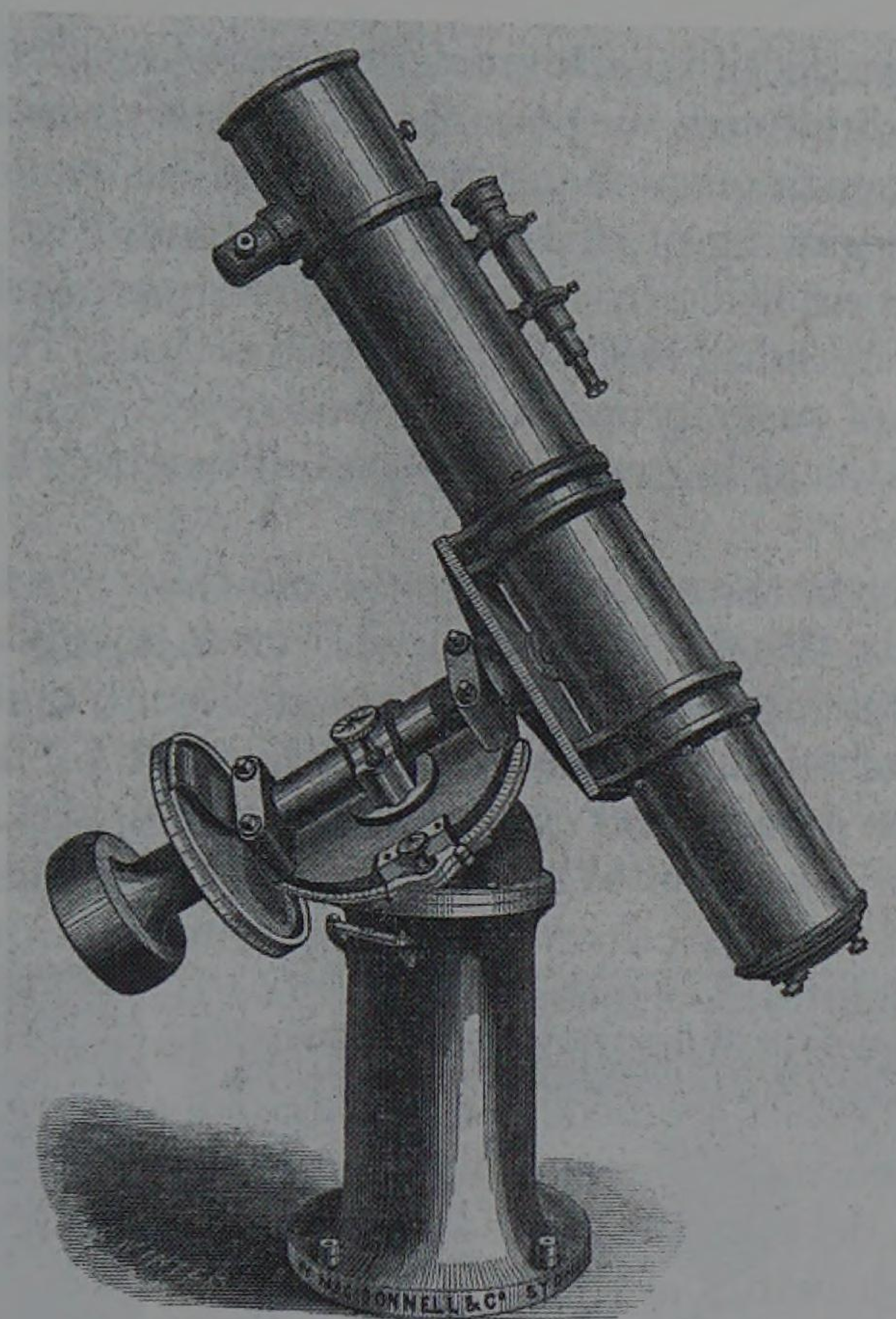

Figure 33. Dr Wright's 21.6-cm Browning-With reflector (Orchiston Collection).

Wright also looked out for the black drop, but "The margin of *Venus'* disk continued sharply and beautifully defined as she passed on to the Sun ... [and] it was clear to me that there was no "black drop" nor any such elongation or distortion of the black edge of *Venus* that could be taken for it." (*ibid.*). Once Venus was well past second contact, Wright (1883: 59) spent an hour unsuccessfully searching for any evidence of a Venusian satellite.

During the egress phase, Wright (*ibid.*) was greeted with equally magnificent seeing and views of Venus. Again there was no black drop, but "The edge of the planet which was in contact with the Sun's limb was now observed to assume a square form, by the blunting or rounding off of the solar cusps." This only lasted for about half a minute. When Venus was further off the Sun, Wright (*ibid.*) noticed "... the reappearance of the halo around the dark body of the planet again throwing

that portion of her disk (as at ingress) into relief against the sky." The halo gradually brightened, and (unlike at ingress) was non-uniform in thickness, being most conspicuous on the north-eastern quadrant of the planet. Wright's drawing of this 'halo' is shown in Fig. 34, and closely resembles the one recorded by Russell (cf. the drawing second from the right in Fig. 14). Wright (1883: 60) also noted that "The same appearance of shadings of rusty brown colour was observed at the margins of the disk of Venus, as at ingress, as she passed onwards from off the Sun ..."

Russell records the observations of another Sydney-based amateur astronomer, a Mr F. Allerding, who used an 8.9-cm (3.5-in) refractor stopped down to 5.1-cm (2 inches) and located at a longitude of 10h 04m 48.5s E of Greenwich and a latitude of 33° 52′ 01″ S. Allerding saw and timed the ingress and egress contracts, but did not place much credence on their accuracy. What particularly interests us, though, is his observation of the black drop "... at the Internal Contact at ingress I saw a drop which formed into a cone (Plate II, fig. 12), and when it (the cone) had nearly disappeared, it seemed to stretch out to a fine thread to which Venus seemed to be attached, reaching to the Sun's limb (fig. 13); then the line instantaneously disappeared ... but Venus was already well detached from the Sun's limb ..." (Allerding, 1883: 60). Allerding's drawings are shown here in Fig. 34.

Independent Observers. Beechworth.

A newspaper summary of Australian transit observations mentions that at the picturesque northern Victorian country town of Beechworth "... a private observing station [was] established by Dr. James Anderson, who was at one time Professor of Mathematics at Columbia College (U.S.), and who had come from America for the express purpose of observing the transit. He had the satisfaction of getting capital observations of first internal contact, but afterwards the sun became overcast, and nothing further could be done." (The transit of Venus, 1874d). No further details are provided.

Independent Observers. Goldsborough.

Australia's leading nineteenth century telescope-maker was Captain Henry Evans Baker. In 1886 he was appointed founding director of James Oddie's private observatory in Ballarat, where he soon after constructed a 66-cm (26-in) Newtonian reflector – for many years the sec-

ond largest reflecting telescope in Australia (see Orchiston, 2003). Back in 1874 Baker was living in the nearby gold-mining town of Goldsborough, and this is where he observed the transit, using an equatorially-mounted refractor of unspecified aperture "... regulated by a temporised sand clock, which acted most truly." (The transit of Venus, 1874d). Baker obtained times for all four contacts.

Independent Observers. Melbourne.

As in Sydney, there must have been a number of amateur astronomers who made a serious attempt to observe the transit and time the contacts, but the only one of these specifically mentioned in the literature I examined was a Thomas Pearce of Royal Park, who used a 22.9-cm (9-in) reflector and obtained times for the second, third and fourth contacts. First contact was clouded out (*ibid.*).

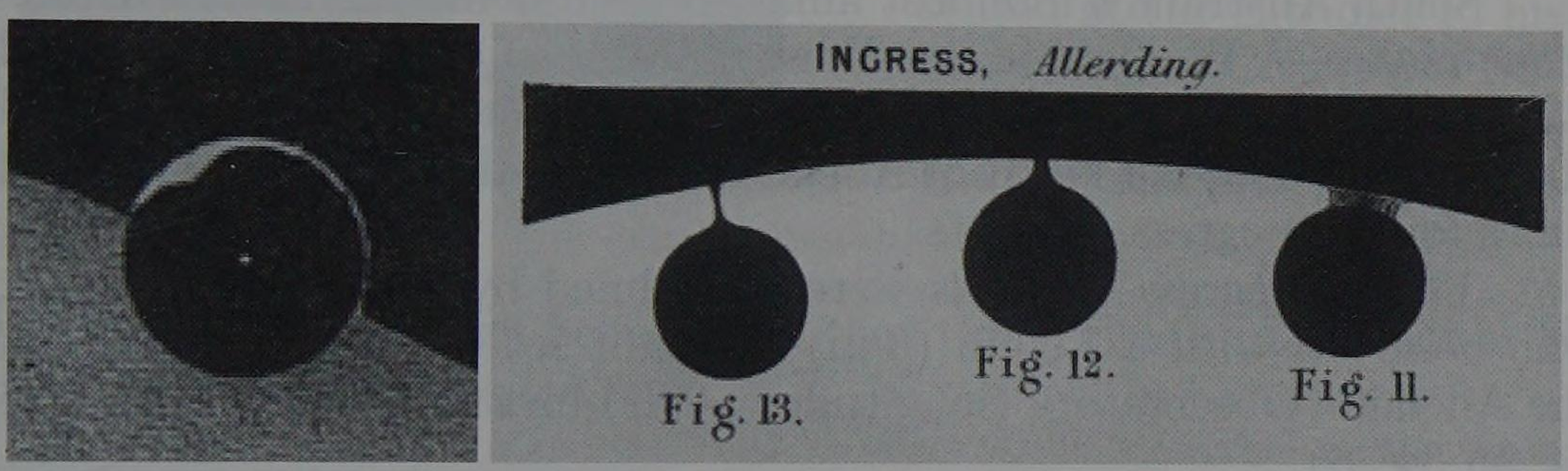

Figure 34. Left: Wright's drawing of the 'halo' seen at egress (adapted from Russell, 1892: Plate XXIII). Right: Allerding's ingress drawings (after Allerding, 1883: Plate II).

Independent Observers. Geelong.

The 30 December 1874 issue of the *Illustrated Australian News* newspaper reports that in the Victorian port city of Geelong a Mr. Thomas from the Customs Department projected an image of the Sun onto a screen so that local people could see the transit. However, he also recorded the times of the second and third contacts, and since these were to the nearest second they were presumably based on the time-service provided locally by the Customs Department.

Independent Observers. Adelaide.

In his report to the Royal Astronomical Society, Charles Todd (1883: 95–96) refers to just three Adelaide-based amateur astronomers who carried out serious observations of the transit. Mr T.D. Smeaton observed from his home in North Adelaide (136 chains N and 86 chains E of the Adelaide Observatory), using an 8.9-cm (3.5-in) equatorially-mounted Cooke refractor, and he timed both egress contacts. Towards third contact there was "No black drop, the osculation being perfect, and the cusps of light between the Sun and the planet being quite sharp. The dark planet was seen against the bright sky when half off the Sun, and edged with a bright margin. This I interpret as the twilight of Venus, proving the presence of an atmosphere." (cited in Todd, 1883: 95). This egress illumination was also reported by other observers (e.g. see Figs. 18 and 30).

South Australia's foremost amateur astronomer and pioneer telescope-maker, A.W. Dobbie (see Edwards, 1994; Orchiston, 2003), used a 21.6-cm (8.5-in) reflector to observe the transit from his home, located 800 metres N and 3.4 km E of Adelaide Observatory. He also obtained times for both egress contacts.

The two egress contacts were also timed by Mr F.G. Singleton, who observed with a 7.6-cm (3-in) refractor set up in the grounds of the Adelaide Observatory (longitude = 09h 14m 21.3s E and latitude = $34^\circ\,55'\,34''$ S).

Independent Observers. Hobart.

After Tebbutt, Francis Abbott (Fig. 35) ranked as Australia's foremost amateur astronomer (see Orchiston, 1992), and he maintained a well-equipped observatory at his home in suburban Hobart. In the lead-up to the transit, Abbott published three different papers in the journal of the Royal Society of Tasmania, alerting Taswegians to the forthcoming spectacle and stressing its scientific importance (Abbott, 1864, 1873, 1874), so it was unfortunate that the sky was so unkind on 9 December. *The Mercury* newspaper reports that "At Mr. Abbott's private observatory in Murray-street, Sir James Wilson, Bishop Bromby, Captain Barnard, and Mr. T. Giblin, assisted Mr. Abbott in his observations. The third contact was seen very distinctly, but none of the others." (The transit of Venus, 1874e).

Observations of the transit were also made from Elizabeth Street, Hobart, by a watch-maker named Barclay, who was assisted by a Mr

Figure 35. Francis Abbott seated at the entrance to his observatory (Courtesy: Tasmanian Museum and Art Gallery, Hobart).

Roberts of Trinity High School, and they timed the third contact at 3h 37m 29.6s local time (*ibid.*).

2.2. New Zealand

The 1874 transit of Venus promised to be the most important astronomical event in New Zealand since the European settlement of the country, and it attracted enormous public attention. Not only did the Government plan transit observations, but amateur astronomers throughout the nation readied themselves for this once-in-a-lifetime event which promised views of the entire transit and all four contacts (unlike the later 1882 transit, when only the egress phase would be visible). Members of the general public also were catered for, thanks to a booklet titled *December 9, 1874. The Transit of Venus and How to Observe It* (Stock, 1874), which was penned by Archdeacon Arthur Stock (Fig. 36), the talented and dedicated Astronomical Observer at the Government's Colonial Observatory in Wellington.

Because of New Zealand's unique geographical location, English (Airy, 1881), French (Bouquet de la Grye, 1882; Filhol, 1885), German (Auwers, 1887–1898) and U.S. (Newcomb, 1880) transit parties were attracted to the sunny South Island and to three of New Zealand's off-

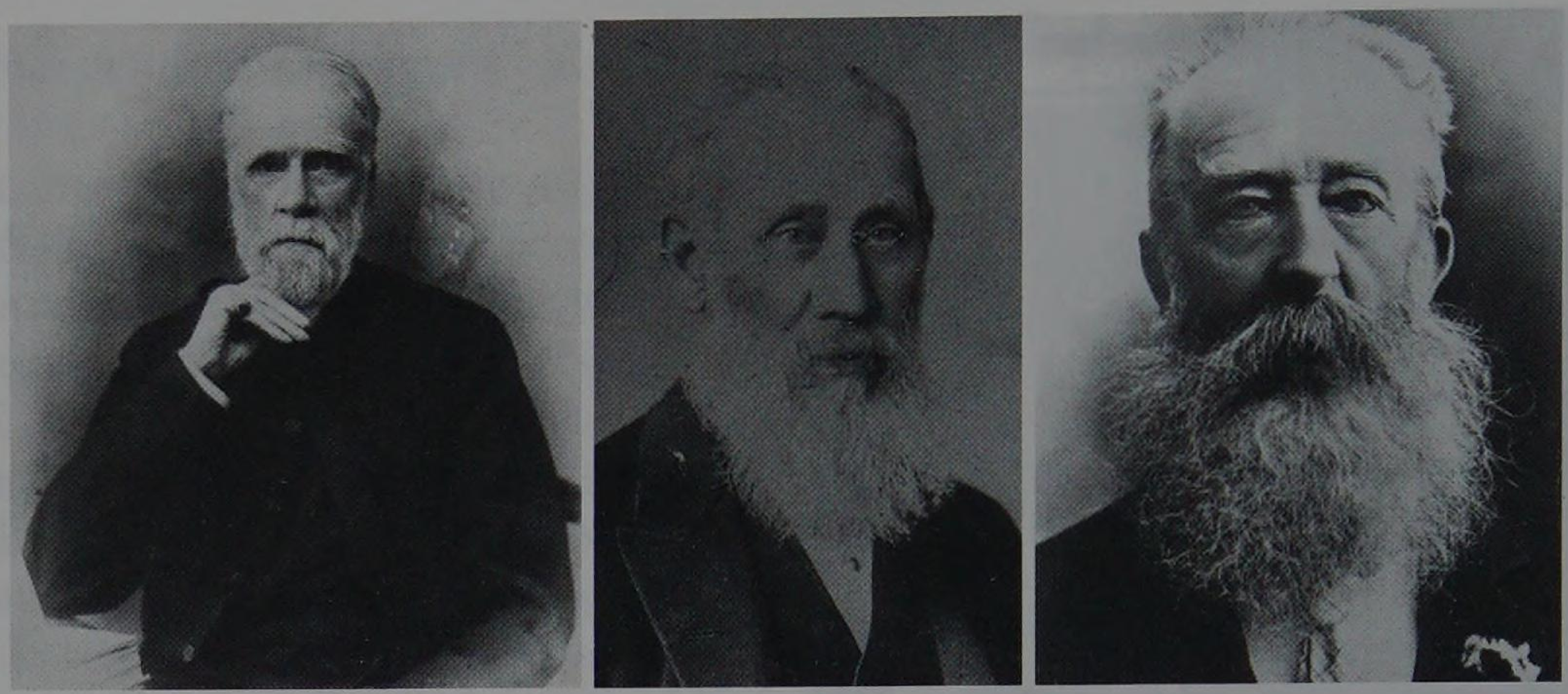

Figure 36. Left: Archdeacon Arthur Stock. Middle: Alfred Barrett Biggs. Right: John Grigg (Orchiston Collection).

shore islands: the Chatham Islands, due east of New Zealand, and to the Auckland Islands and Campbell Island, far to the south, in New Zealand's frozen, wind-swept, inhospitable sub-antarctic zone. The British, under Major Palmer, also arranged a network of official subsidiary stations, which were manned by the following New Zealand observers: Captain Heale (in Auckland), Henry Severn (Thames), Archdeacon Stock (Wellington) and J.T. Thomson and J. McKerrow (Dunedin). All were supplied with time, by telegraph, from Burnham (The transit of Venus, 1874b). In addition, a number of amateur astronomers in Auckland, Featherston, Wellington, Nelson and Dunedin prepared independently for this important event. Regrettably, inclement weather prevented the French party on Campbell Island from seeing the transit (Lauga, 2004: 302), and this same fate befell many of those on the North and South Islands of New Zealand (The transit of Venus, 1874c; The transit of Venus, 1874f). Yet some of the astronomers in Auckland, Canterbury and Otago (see Fig. 2 for localities), and the overseas parties on the Chatham Islands and Auckland Island, did meet with a modicum of success – as the following accounts will demonstrate.

International Expeditions. Burnham: the British Expedition.

Leading the British expedition to New Zealand was Major H.S. Palmer, R.E., aided by Lieutenants H. Crawford, L. Darwin and H. Praed. The site they selected, after carefully considering seven different options (Palmer, 1874a), was about 730 metres north-west of Burnham Rail-

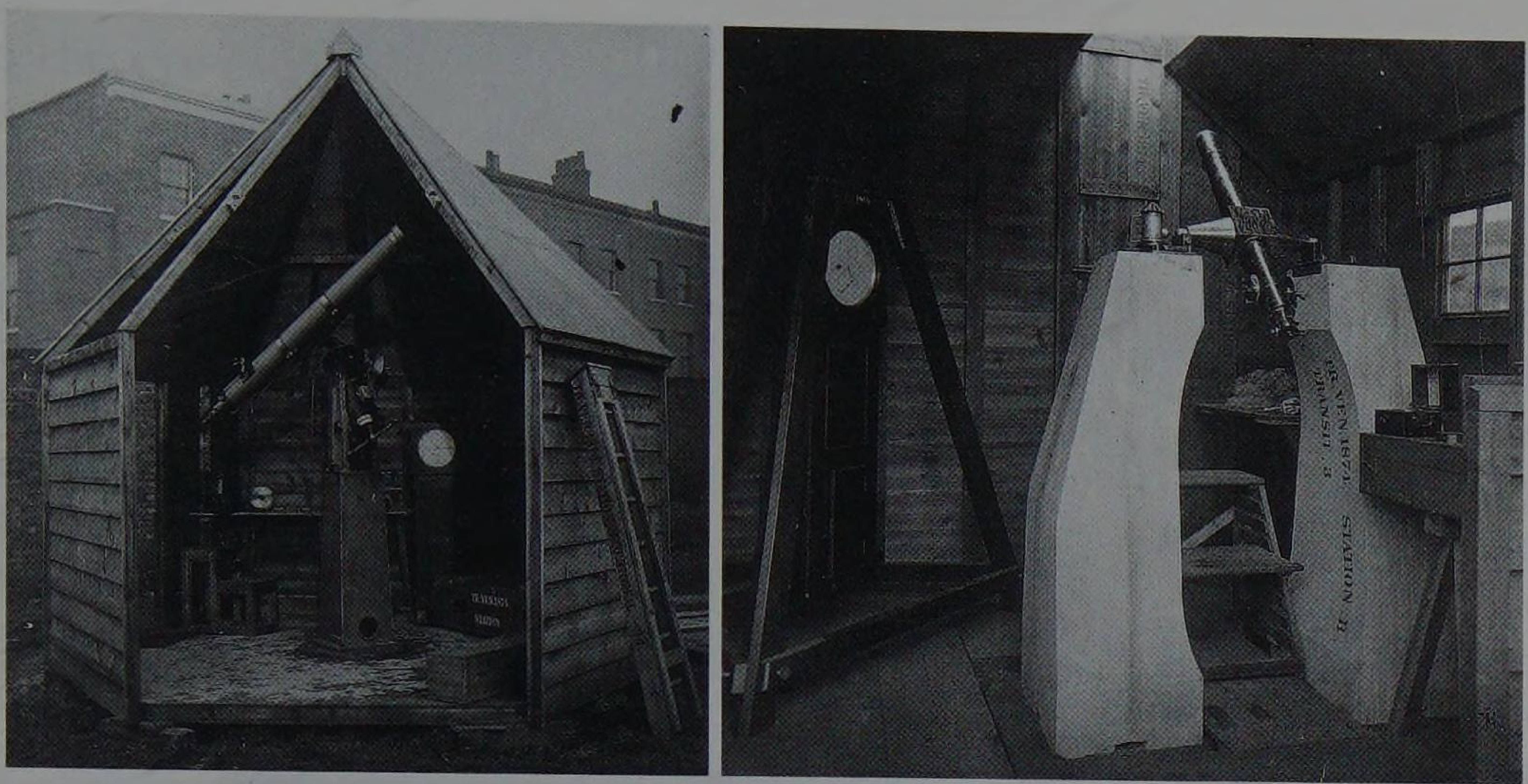

Figure 37. Simms refractor and Simms transit telescope (*right*) used at the British transit stations (Courtesy: RAS Archives, London).

way Station, on the expansive Canterbury Plains (which stretch from Christchurch westwards to the South Alps, and extended ~150km in a NE-SW direction). The railway station was on the main N-S telegraph line, which provided Palmer with a means of transmitting time signals to the 'satellite' stations throughout the nation (Airy, 1881: 484). Meanwhile, acting on advice from New Zealand authorities (Thomson et al., 1874) and in order to allow for possible inclement weather at Burnham, Palmer directed Lieutenant Crawford and Captain Williams from the *Merope* to establish a separate observing station at Naseby, in dry, sunny northern Otago (The transit of Venus, 1874b). This was furnished with a 10.2-cm (4-in) Simms refractor, a portable transit telescope by Shaw, and an astronomical clock by Dent (Palmer, 1874a, 1874b).

The coordinates of the Burnham transit station were: longitude = 11h 29m 13.1s E and latitude = 43° 36′ 48″.1 S. The main astronomical instruments used there were a 15.2-cm (6-in) Simms equatorial (Fig. 37), a transit telescope by Simms (Fig. 37), a Dallmeyer photoheliograph (Fig. 38), a 38.1-cm (15-in) diameter Troughton and Simms azimuth instrument with a 5.7-cm (2.25-in) objective, and an astronomical clock made by Arnold but modified by Dent. Major Palmer was particularly pleased with their quality, commenting: "The instruments throughout are but of moderate size, but are the best of their kind,

Figure 38. Dallmeyer photoheliograph used at the British transit stations (Courtesy: RAS Archives, London).

and give evidence of remarkable preparation and care and forethought which the Astronomer-Royal has bestowed upon the English part of the undertaking for the actual observation of the transit." (The transit of Venus, 1874a). With the instruments came prefabricated equatorial, photoheliograph, transit and altazimuth huts (Simmons, 1880). In reporting on their preparations leading up to the transit, Palmer (1874a) heaped praise on the New Zealand and Provincial Governments: "It is impossible to speak too well of the readiness with which all facilities in their power have been afforded to us ... Everything has been done to assist our operations, and to lessen our expenses."

On the morning of 9 December, unfavourable weather prevented observation of the first contact, and when the clouds thinned sufficiently Venus "... was then seen to have advanced apparently about three-eighths of her diameter on the Sun. Both Sun and planet could only be just made out through the clouds, without any coloured shade

to the eye-piece." (Airy, 1881: 493). Over the next twelve minutes or so, Palmer used the Simms refractor to make a dozen unsuccessful attempts to take micrometric measurements of the transit during gaps in the clouds. Immediately prior to second contact, "... the Sun showed again, when the cusps were about one-twentieth of a diameter apart, and connected by a dimly marked ligament, not nearly so sharp as the "black drop" of the model in full sunlight." (Airy, 1881: 494). Three and a half seconds later, "... the ligament seemed to undergo a change in depth of colour, but clouds prevented me from seeing whether any streak of light connecting cusps played across it." (*ibid.*). Just three seconds later clouds intervened, and prevented further observations of the ingress phase. Nearly fifteen minutes after the estimated time of second contact, the clouds cleared sufficiently for Palmer to attempt further micrometric observations, but he judged the results as "... very irregular, and ... of little use." The remainder of the transit – including the egress contacts – was lost, owing to clouds and rain, and the Sun only emerged ten minutes after fourth contact. As if to mock the astronomers, it then shone brilliantly until near sunset!

Palmer may have had only limited success at Burnham, but the weather conspired against Lieutenant Crawford making *any* observations at Naseby (Airy, 1881: 484).

International Expeditions. Queenstown: the U.S. Expedition.

After dropping off two Australian-based transit teams in Hobart, the U.S.S. *Swatara* crossed the Tasman Sea with two parties destined for New Zealand waters, and anchored in Bluff Harbour on the extreme southern tip of the South Island of New Zealand (see Fig. 3). The intention, initially, was to establish a transit station at Bluff, but Dunedin astronomers recommended an inland site, in sunny Central Otago (see Thomson et al., 1874). Queenstown, on the shores of Lake Wakatipu and at longitude 11h 14m 40.4s E and latitude 45° 02′ 07″ S was subsequently chosen (Newcomb, 1880: 21). The Queenstown transit party comprised Dr C.H.F. Peters from Hamilton College, his Assistant Astronomer Lieutenant E.W. Bass (from the Corps of Engineers), and four photographers, C.L. Phillippi, Israel Russell, E.B. Pierson and L.H. Aymé (Dick, 2003: 255), and they had access to the same sorts of instruments as issued to all of the U.S. stations (for details see Orchiston, Dick and Love, 2000). A plan of the Queenstown transit station is reproduced in Fig. 39, while Fig. 40 shows the Transit and Equatorial Houses.

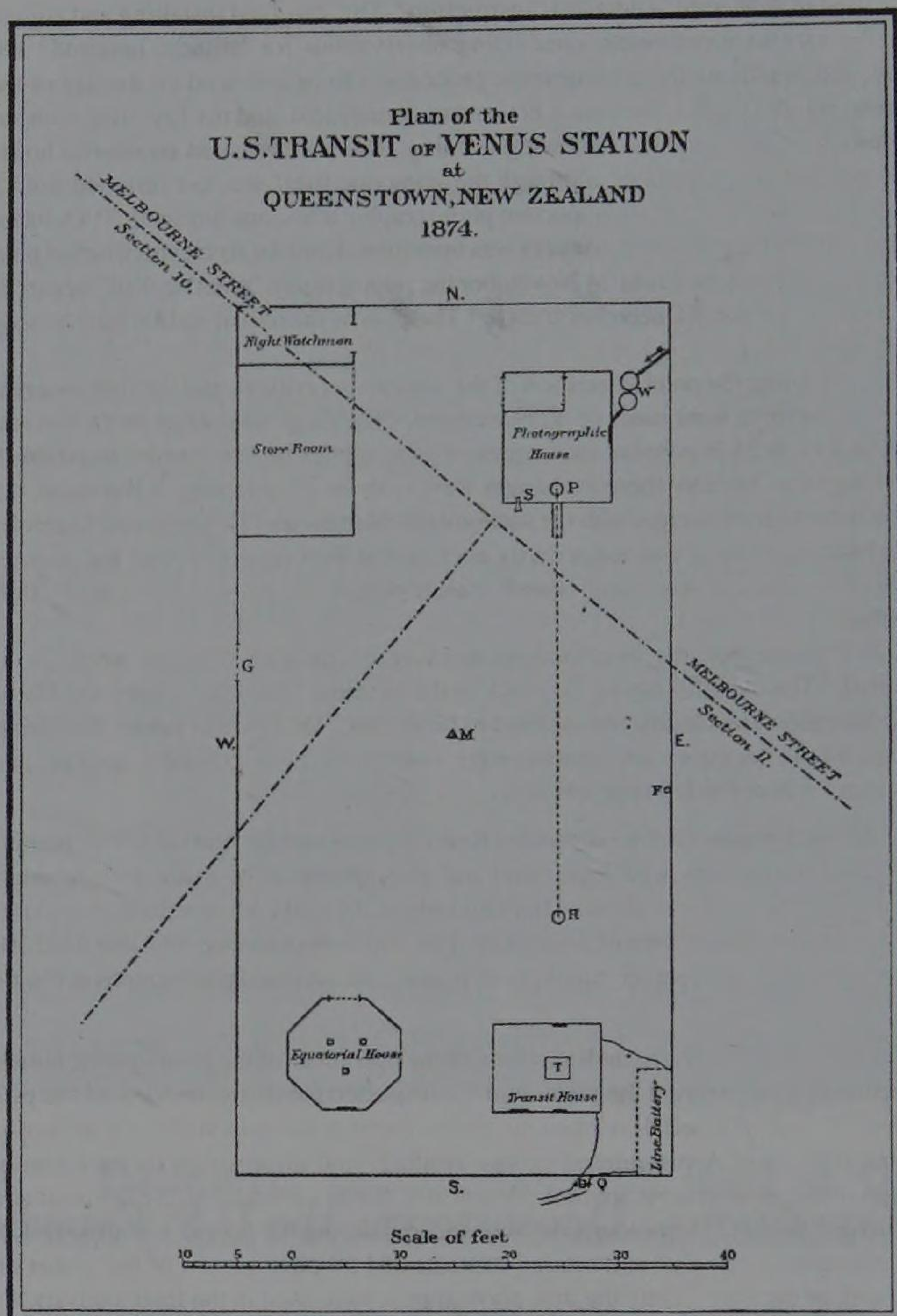

Figure 39. Plan of the Queenstown transit station (after Orchiston et al., 2000: 35).

At 5 am on 9 December the sky was cloudy and stormy, but – miraculously – the Sun appeared just two minutes before first contact, "... permitting observations of Equatorial and photographs to be made without interruption for 1⅔ hours about. After that only at intervals, up to within 16 minutes before computed time of 3^d contact. The Sun then remained invisible until ... after 4^th contact." (Peters, 1874). In all, 237 photographs of the transit were obtained, 178 of the ingress contacts and 59 of Venus superimposed on the Sun's disk (Newcomb, 1881: 439–440). Peters was observing with the Clark refractor, and he specifically noted the absence of the black drop at second contact (Peters, 1874). Between second and third contacts he obtained a series

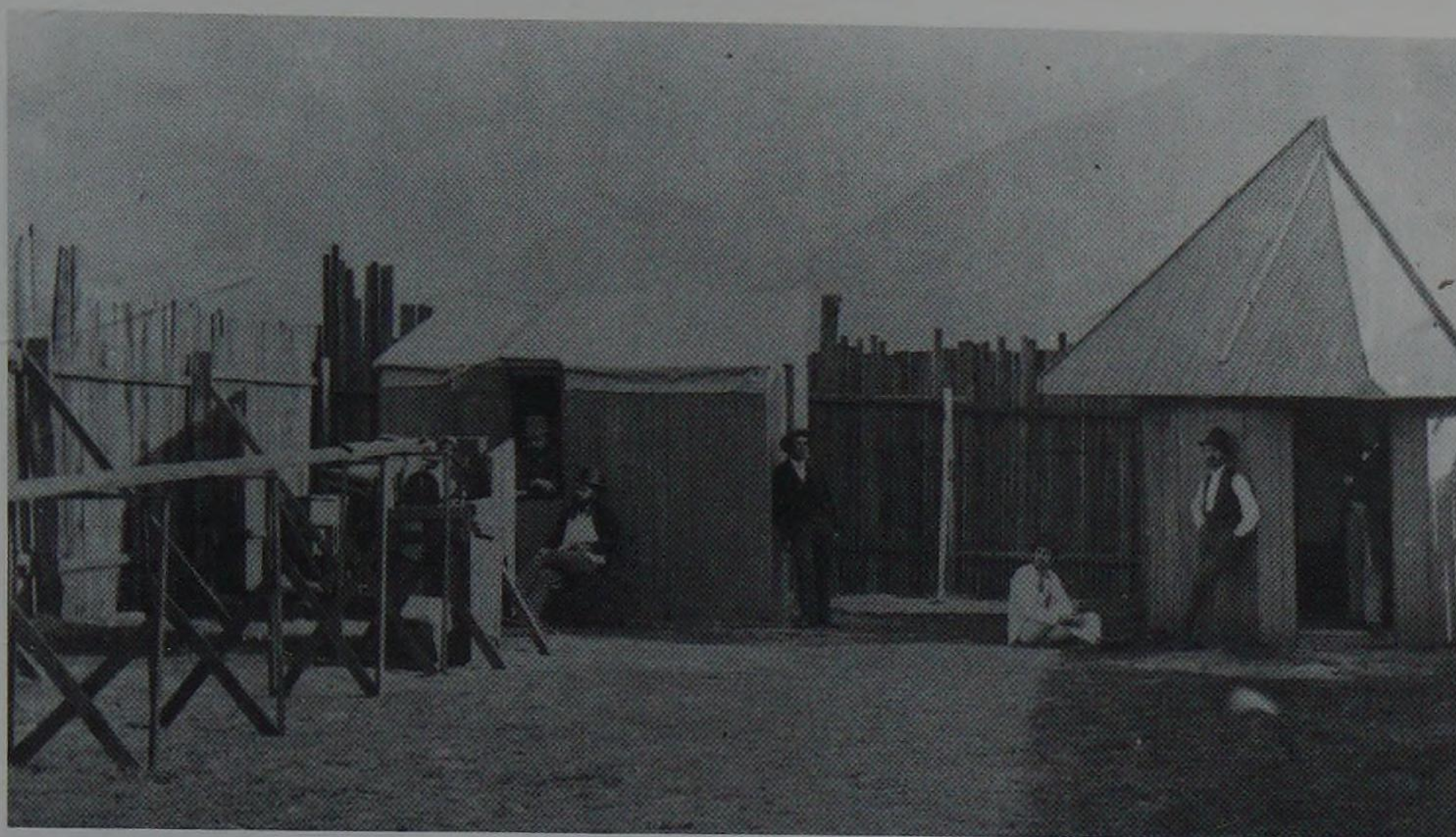

Figure 40. Part of the Queenstown transit station, showing the Transit House and heliostat (left) and the Equatorial House (right) (Courtesy: Hocken Library, Dunedin).

of micrometric measures of Venus' position relative to the Sun's limb (see Newcomb, 1880). In summary, Peters was very pleased with the outcome of the expedition: "The instruments and appliances worked admirably, and everything passed off well." (*Lake Wakatip Mail*, 1874).

International Expeditions. Chatham Islands: the U.S. Expedition.

The final Southern Hemisphere U.S. transit party was assigned to the Chatham Islands, New Zealand territory to the east of the South Island (Dick et al., 1998), and the contingent there comprised Chief Astronomer, Edwin Smith from the U.S. Coast Survey, Assistant Astronomer, Albert H. Scott (also from the Survey), the photographers, Otto Beuhler and W.H. Rau, and an instrument-maker named Sumner Tainter (Dick, 2003: 255). They were also joined by an interested local (see Baucke, 1928). Their astronomical 'houses' and equipment mirrored that found at other U.S. 1874 transit stations, and Figs. 41 and 42 provide close-ups of the photographic telescope heliostat, the equatorial house, and the broken tube transit telescope in the transit house. The transit station was set up at Whangaroa, at longitude = 12h 13m 11.8s W and latitude = 45° 49′ 03.″2 S (Newcomb, 1880: 21).

From the listing in Newcomb (1880: 135) and the account given by Baucke (1928), it is apparent that first and second contacts were

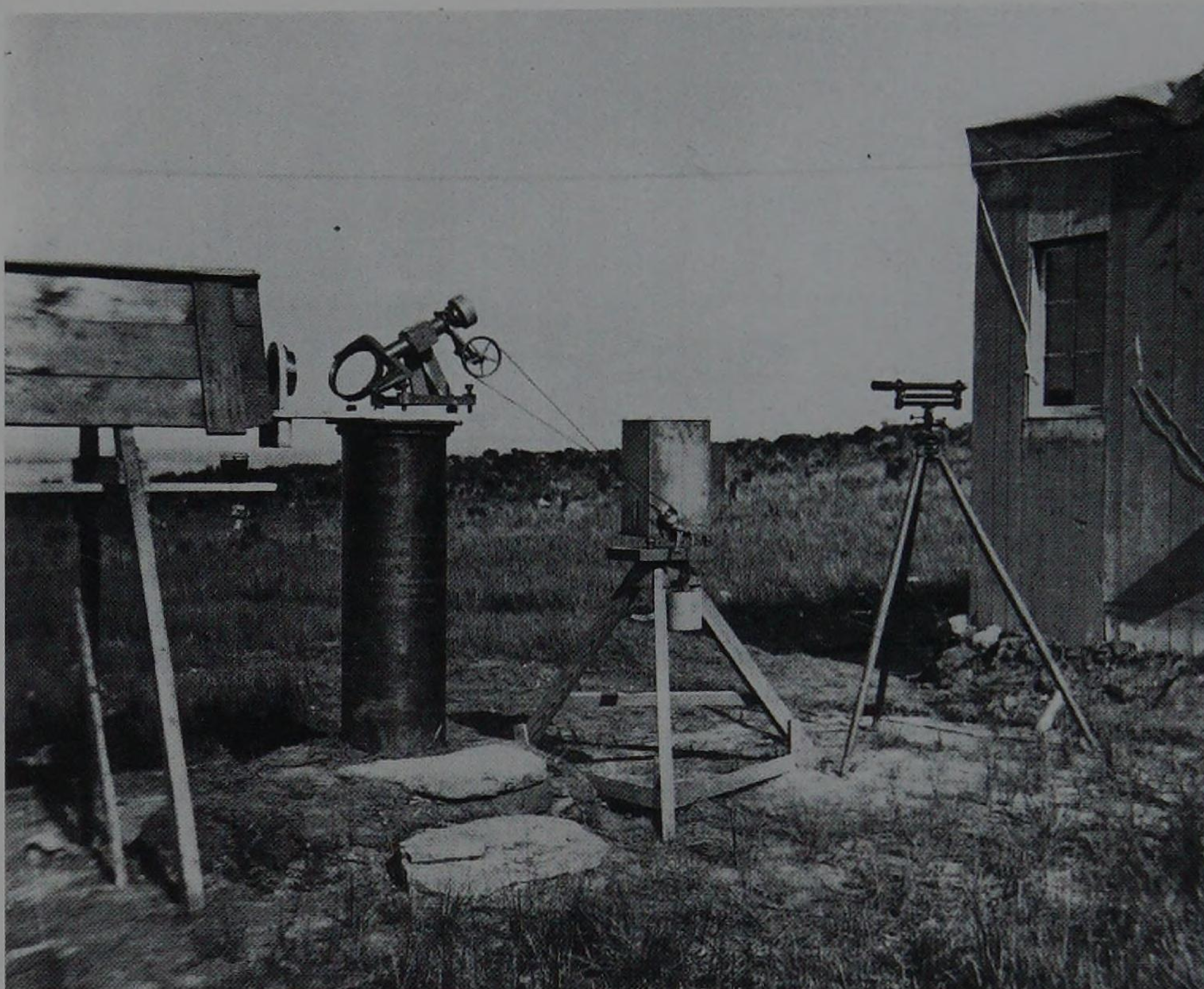

Figure 41. Chatham Islands photographic telescope heliostat and, at right, part of the Transit House (Courtesy: Alexander Turnbull Library, Wellington, PAColl-0058-02).

observed, but only eight photographs were obtained (Dick, 2003: 259; The transit of Venus. The United States Expedition ..., 1882).

International Expeditions. Auckland Islands: the German Expedition.

The German station at Port Ross, on Auckland Island (longitude = $166° 13' 27.9''$ E; latitude = $50° 32' 14''.4$ S), was one of six set up by Germany for the 1874 transit (see Duerbeck, 2004). Members of the Auckland Island expedition were: two astronomers, Hugo Seeliger and Wilhelm Schur; two photographers, Hermann Krone and Guido Wolfram; and two assistants, Johannes Krone (Hermann's son) and Hermann Leyser. A comfortable station with prefabricated observatories and a house was set up on the beach at Terror Cover, Port Ross (see Fig. 43), some of the brick footings of which were still visible more than a hundred years later (Ritchie, 1987). The instruments used at this

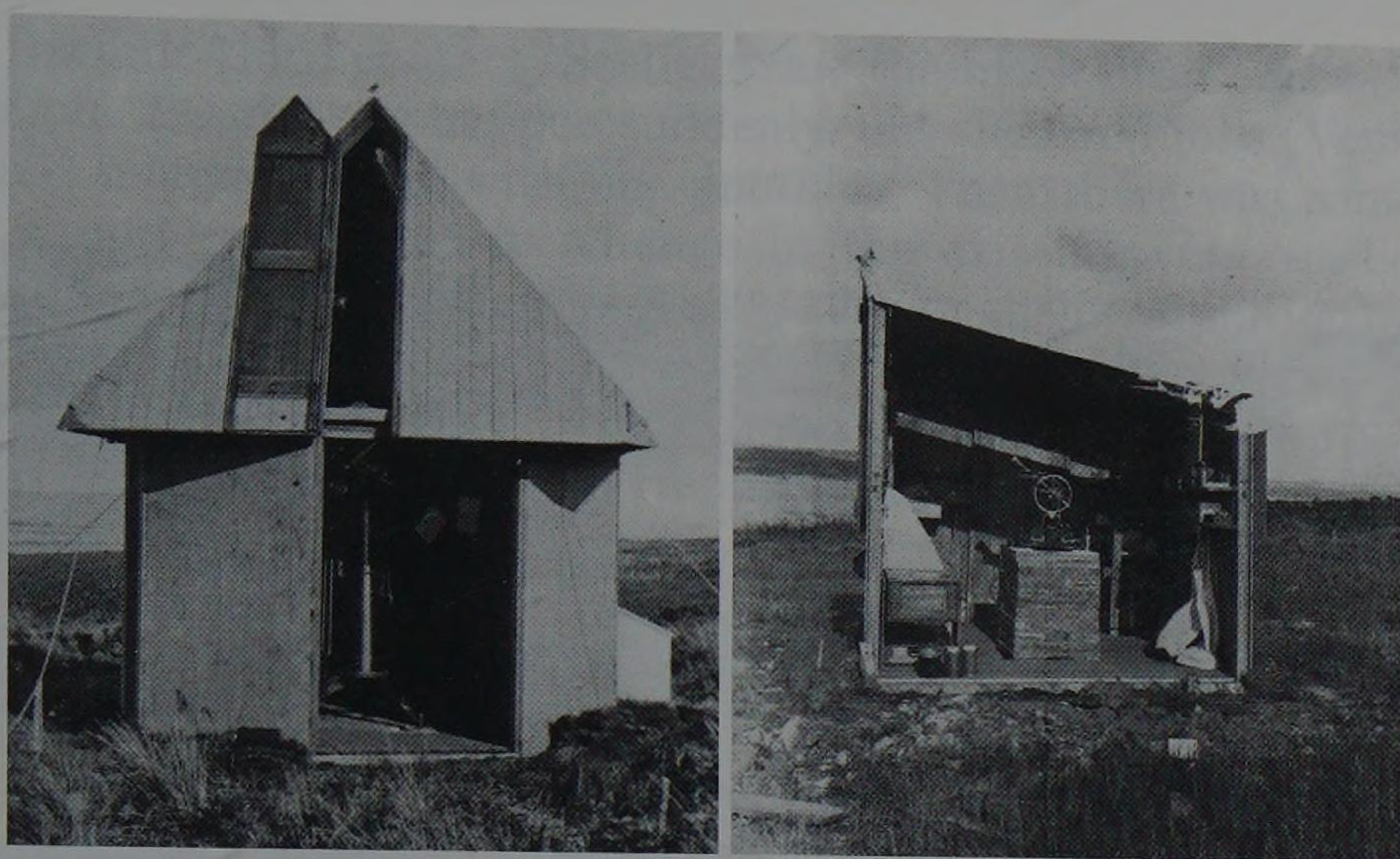

Figure 42. Chatham Islands Equatorial House (left) and Transit House with transit telescope (right). Courtesy: Alexander Turnbull Library, Wellington, resp. PAColl-0058-05 and PAColl-0058-03).

transit station were: a 7.6-cm (3-in) Fraunhofer heliometer (loaned by Göttingen Observatory), used to measure the motion of Venus across the solar disk; a 10.7-cm (4.2-in) Steilheil photoheliograph (Fig. 44), which was designed to photographically record the transit; 11.7-cm (4.6-in), 8.25-cm (3.25-in) and 7.3-cm (2.9-in) Fraunhofer refractors (for visual observations of the ingress and egress contacts); a Pistor & Martin transit telescope; and time-keeping and meteorological equipment (Auwers, 1889; Duerbeck, 2004).

Although light rain fell before the transit started, as it turned out all the preparations proved worthwhile, and Seeliger and his colleagues did succeed in observing much of the transit. Passing clouds made it difficult to time the two ingress contacts, but soon after second contact the clouds dispersed and the remainder of the transit was visible (although by egress the solar image was far from ideal). During the transit, Seeliger observed with the heliometer, Schur with the largest conventional refractor, Wolfram with one of the smaller refractors, while Hermann Krone exposed no less than 115 plates with the photoheliograph (Auwers, 1889: 202–206). Most of the photographs showed Venus on the Sun's disk (and one of these is reproduced here in Fig. 44), but the last six plates were exposed immediately prior to, and during, the egress contacts.

Figure 43. Auckland Island transit station (Courtesy: Agfa Photo-Historama, Cologne).

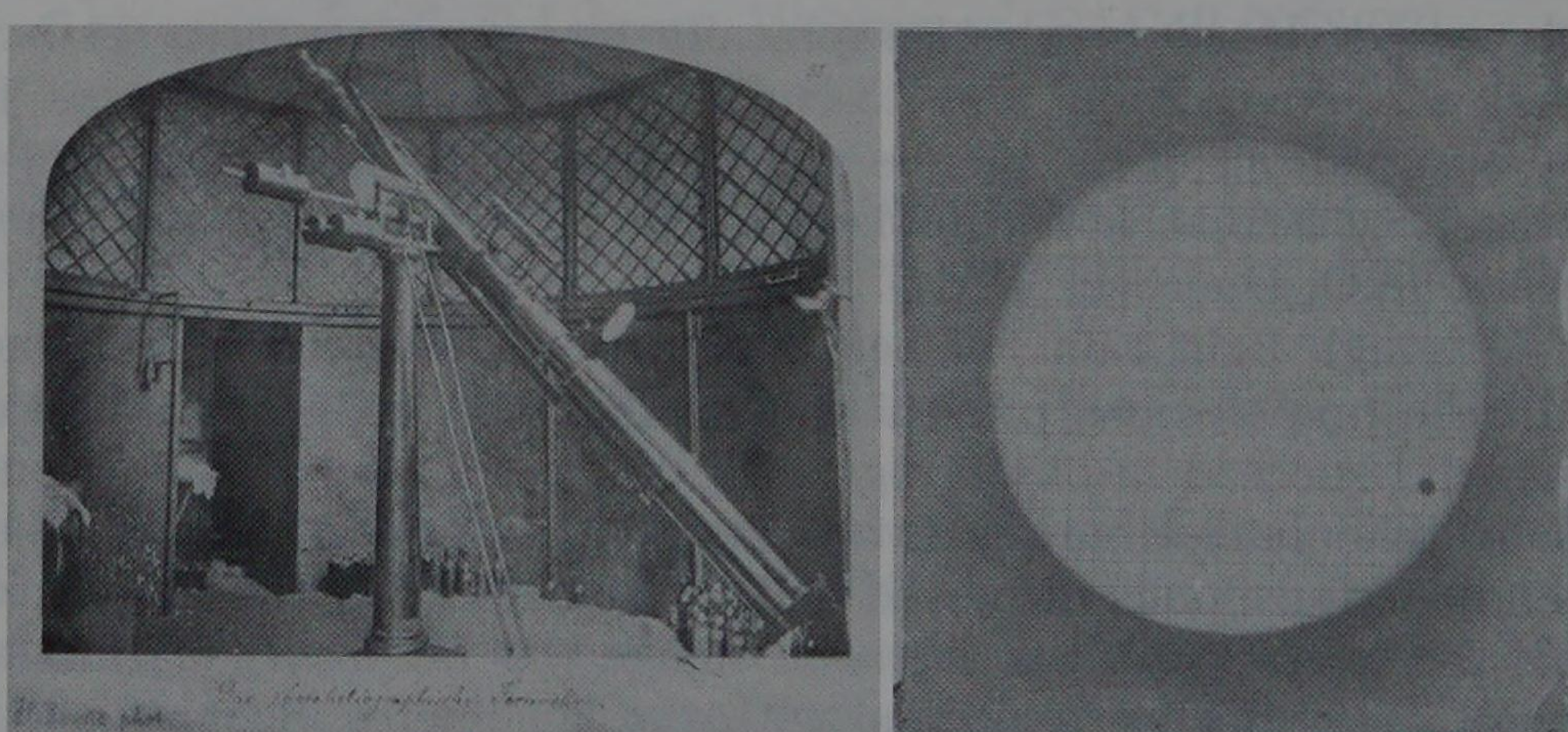

Figure 44. Steilheil photoheliograph at the Auckland Island transit station, and photograph of the transit (Courtesy: Krone-Sammlung, Dresden).

Towards third contact, Seeliger saw the black drop effect, but its formation "... did not happen suddenly, but the two limbs (Venus and the Sun) merged slowly with one another. Then there was a moment when a noticeable intensity change in the existing very washed-out darkening took place." (Auwers, 1889: 199; English translation). Wolfram also clearly saw the back drop effect: At "5h 49m 39s a darkening occurred between both limbs, which I perceived as the moment of drop formation ..." (*op. cit.*: 201). He also remarked that unlike with the transit of Venus apparatus used for practice observations, in reality when the back drop develops "... one sees that a broad band forms which is darkest at that location where the limbs [of Venus and the Sun] are closest to each other, and this gradually fades at the upper and lower edges." (*ibid.*). Unfortunately, Schur did not make a successful observation of the third contact, but all three astronomers did see, and time, the fourth contact.

Independent Observers. Auckland.

Although Captain Heale was prevented from observing the transit, another transit team, located in a different Auckland suburb, had some success. Professor S.J. Lambert and Messrs, Martin, Pond and Redfern (a photographer) spent four months setting up their transit station in Hobson Street, which contained telescopes, photographic equipment, and a chronometer. Time was provided via telegraphed signals (Transit of Venus, 1874c). Lambert timed the first contact and eight minutes later the black drop was observed, which was followed by second contact. Soon after this, clouds moved in and prevented any further observations of the transit. However, during the ingress phase, "A good many sun pictures of great nicety were obtained." (*ibid.*).

Independent Observers. Nelson.

Both ingress and egress contacts were visible from Nelson, but during the intervening period clouds and rain prevented observations being made. *The Daily Southern Cross* newspaper reports that an amateur astronomer by the name of Captain Sharp succeeded in timing the egress contacts with the aid of a chronometer (The transit of Venus, 1874f).

3. The 1882 Transit

Despite the disappointing weather conditions that greeted many New Zealand observers, the overall Australasian transit observations of 1874 appeared to be an overwhelming success, leading to expectations that this would be repeated on 7 December 1882 during the second transit of the nineteenth century.

There were, however, two factors – other than the weather – that might militate against this. Firstly, the 1882 transit would already be in progress at sunrise in New Zealand and Australia, so it would only be possible to observe, and time, the third and fourth contacts. And secondly, photography had not lived up to expectations in 1874 (e.g. see Airy, 1881: Appendix V), and its use during the 1882 transit was therefore questioned by many (Lankford, 1987). Some nations decided to rely solely on visual observations, but others, including the Americans and some of the Australian colonial observatories, determined to persist with their photographic endeavours.

3.1. Australia

Following the resounding success of the 1874 transit programs, the Australian professional observatories all planned ambitious programs for 1882 (Baracchi, 1914: 364-365), but inclement weather intervened and prevented those at all six Sydney Observatory transit stations, at Adelaide Observatory, and at the Melbourne Observatory transit station at Sale, in Gippsland, from carrying out observations. Rain also denied John Tebbutt a chance to see his second transit of Venus, and also washed out was Captain Morris' private transit party that had journeyed all the way from Britain to Jimbour, in Queensland (see Haynes et al., 1996: 86–88 for a summary and a photograph). The few stations that did witness this transit are discussed below. It should be noted that no U.S. transit stations were sited in Australia for the 1882 event.

Quite apart from its scientific importance, this transit – like its predecessor – titillated the general public. In Hobart, where the transit was clearly visible, "Great numbers of people got up to witness this phenomenon, and several private observatories were erected in the residences of prominent citizens." (The transit of Venus, 1882a). These actions would have been mirrored in other towns and cities throughout Australia (and New Zealand).

Colonial Observatories. Melbourne Observatory.

Melbourne Observatory again organised an ambitious transit program, but fate dictated that those at only two stations would get to observe the event. At the Observatory itself, the Sun eventually broke through a cloudy sky and Robert Ellery (Fig. 11) used the 20.3-cm (8-in) Simms refractor (cf. Fig. 24) to record both egress contacts. Prior to third contact conditions were far from ideal, with the limbs of the Sun and Venus "... *boiling violently.*" (Stone, n.d.: 70) but he was able to take measures with a double-image micrometer of the distance of Venus from the solar limb. Just before third contact, Ellery reported "... there was a flickering junction of the limbs, and then an appearance like *Baily's beads*, quite distinct, but flickering for some seconds." (*ibid.*). He identified third contact as "... when the solar light flickering around the edge of Venus ceased to show broken beads of light, and immediately after a break in the Sun's limb was apparent." (*ibid.*). Immediately following the contact he noticed that "As the advancing limb of Venus emerged from the solar disc, a clear thread of silvery light was continued around it, – a very thin thread." (*ibid.*). At 17:53 local time, as fourth contact approached, he first saw "... a pale halo, or rather disc, of uniform light, very dim, but with a sharp outline symmetrically surrounding Venus outside Sun's disc. Estimated radius = three diameters of the planet, very distinct at 17h. 54m." (*ibid.*; cf. Figs. 18 and 30). The halo was still there four minutes later, but disappeared 3.5 minutes before fourth contact.

At Melbourne Observatory, J.E. Gilbert carried out independent observations using an 11.4-cm (4.5-in) equatorially-mounted Simms refractor and a chronograph. Despite the "boiling limbs" also noted by Ellery, he was able to record the third and fourth contacts. In his report, published in Stone (n.d.: 71), Gilbert states that three minutes before third contact he saw "... a narrow luminous halo surrounded the planet, its form improving wonderfully, being almost circular, the boiling very trifling." Soon after this he observed the formation of "... a *Chinaman's cap* ..." (*ibid.*; cf. Fig. 25). Between third and fourth contacts, "The outline of the planet could be traced by a faint but sharply-defined luminous edge, until it was about three parts off the Sun." (*ibid.*; cf. Figs. 18 and 30).

According to a newspaper report (The transit of Venus. The United States Expedition ..., 1882), "Twenty-three good photographs ..." of the transits were also obtained at Melbourne Observatory. The

only instrument that could have been used to obtain these was the Dallmeyer photoheliograph (see Clark and Orchiston, 2004).

In order to allow for inclement weather in Victoria, Ellery had decided to establish a transit station in Hobart, the Tasmanian capital, and this was manned by his second-in-command, John White, who also succeeded admirably in recording the egress contacts. The co-ordinates of the observing site were: 09h 49m 19.53s E of Greenwich (longitude) and 42° 53′ 24″ S (latitude). White was furnished with an equatorially-mounted 11.4-cm (4.5-in) Cooke refractor and a Molyneux chronometer, and was assisted by the newly-appointed Tasmanian Government Meteorological Observer, Captain John Shortt. White and Shortt enjoyed a clear sky, and at third contact "... Venus was observed to pass over the sun's edge without any distortion, the only imperfection being a serrated edge owing to atmospheric disturbance. There was no appearance of ligament, or black drop." (Transit of Venus, 1882a). After third contact "... a ring of light ..." (Stone, n.d.: 70) was seen round Venus, but this finally disappeared ~5.5 minutes before fourth contact. The times of both egress contacts were recorded (Transit of Venus, 1882a).

Colonial Observatories. Adelaide Observatory.

Charles Todd (Fig. 11) organised an expedition to Wentworth, an inland town in south-western New South Wales (09h 27m 37.18s E of Greenwich and latitude 34° 06′ 24.″7 S), where he successfully observed the third contact with an 11.4-cm (4.5-in) equatorially-mounted refractor (see Edwards, 2004). Todd reported that "The Sun rose in an unclouded sky on the day of the transit, and the circumstances were all one could desire. Near the time of internal contact the limb of Venus became somewhat distorted or slightly drawn out towards the edge of the Sun, and it was rather woolly; the Sun's limb too was occasionally boiling, bit I think I succeeded in getting the times of the different phases as exact as the nature of the observation will permit." (Stone, n.d.: 72). The telescope that Todd used had some claim to fame as the Observatory had purchased it from B.H. Babbage, who brought it out to Adelaide with him when he settled there after the death of his father, the computer pioneer, Charles Babbage (*ibid.*). For a detailed account of Todd's Wentworth expedition see Edwards (2004).

Independent Observers. Launceston.

By the time of the 1882 transit, Alfred Barrett Biggs (Fig. 36) had eclipsed Francis Abbott as Tasmania's foremost astronomer (see Orchiston, 1985), and lived in Tasmania's second-largest city, Launceston. Biggs and fellow Launceston amateur, Reverend Canon Brownrigg, planned a careful joint observing program. Biggs used a 7.6-cm (3-in) refractor and Brownrigg a 7-cm (2.75-in) refractor, and these were set up in the front garden of a neighbour's property that offered clear views of the eastern horizon. In order to time the egress contacts they relied on chronometers, pocket chronometers and Brownrigg's sidereal clock. The clock was regulated by transit observations, which were made both prior to and after the transit (*The Tasmanian*, 1882).

Prior to third contact, they searched for evidence of a Venusian atmosphere, but "Of this we were unable to discover any decided manifestation ..." (*ibid.*). Both observers timed the first egress contact, but Biggs was at pains to point out that this was no simple phenomenon:

> "(a) At 5hrs. 50min. 50sec. estimated geometrical contact ... (b) At 5hrs. 51min. 7sec. two or three dark bands, or protuberances, flickered out from the outer edge of the planet, towards and into a band of light, which seemed to splash out from the sun somewhat in advance of the planet and of the sun's regular outline. Canon Brownrigg also noticed the same phenomenon, but made no record of the time ... (c) At 5hrs. 51min. 30sec. this black protuberance became persistent and decided, until the planet was fairly posed across the sun's limb. " (*ibid.*).

Between the two egress contacts, Canon Brownrigg noticed "... a luminosity around and within a portion of the limb of the planet, extending from the rim of the sun outwards, and giving the object a ball-like appearance." (*ibid.*; cf. Figs. 18 and 30). Biggs did not particularly notice this, but instead saw "... a short bright curve close up on each side of the planet, crossing the sun's limb." (*ibid.*), and he was convinced this feature, and the one noted by Brownrigg, "... more than any other observed during the transit, seemed to indicate the existence of an atmosphere." (*ibid.*). Subsequently, both observers timed the second egress contact.

In his concluding remarks, Biggs notes that "Of the "black drop", as usually described, we may say we saw nothing. The appearance

described under (b) and (c) cannot be regarded under the above designations ..." (*ibid.*).

3.2. New Zealand

An ambitious transit program involving amateur and professional observers was planned for New Zealand, and this was designed in close collaboration with the British and U.S. parties that based themselves in Burnham and Auckland, respectively (note that on this occasion there were no French or German parties in New Zealand waters). Most observers were connected to the telegraph, and time signals were distributed to North Island and Nelson observers from an observatory set up by the Government at Mount Cook in Wellington, while other South Island observers relied on the Burnham headquarters of the British transit party for their time signals. And in order to accurately determine the geographical co-ordinates of all observing stations, exchanges of time signals were made between Burnham and Auckland, Burnham and Wellington, Wellington and New Plymouth, and Wellington and "Bidwill's" in the Wairarapa (McKerrow, 1882). New Zealand localities are shown in Fig. 2.

International Expeditions. Auckland: the U.S. Expedition.

Frustrated by the largely unsuccessful Chatham Islands' program in 1874, the Americans on this occasion determined to base their New Zealand transit station in Auckland. The site selected was in the Auckland Domain, and is now covered by an extension of the Auckland War Memorial Museum. Head of the U.S. party was Edwin Smith (who was in the Chatham Islands in 1874), and assisting him was Henry S. Pritchett, Professor of Mathematics and Astronomy at Washington University, St. Louis, and two photographers, Augustus Storey and Gustav Thielkuhl (Dick, 2003: 266; Transit of Venus. Arrival ..., 1882). Four others completed the transit party, one of whom was the Auckland amateur astronomer, J.T. Stephenson (and his observations are discussed below).

The transit station was described in a contemporary newspaper report:

> "The casual visitor to the Domain will see a small space near the old Block House enclosed with an iron wire fence. Inside this have been erected several buildings. The one nearest the Block House contains the transit instrument.

> Another one adjoining, with a revolving roof, contains the five-inch equatorial telescope. In front of the one containing the transit instrument is placed the stand for the heliostat, from which runs the telescopic tube connecting with the dark chamber of the photographers, at a distance of some 38 or 39 feet. But inside the Block House are many appliances of the greatest use. There is fitted up the telephonic apparatus, and the telegraphic instruments, by which Mr. Smith has been enabled to exchange signals with Colonel Tupman at Burnham." (Transit of Venus. Arrival ..., 1882).

The astronomical instruments associated with the transit, photographic and equatorial houses were basically unchanged from 1874 (The transit of Venus, 1882c; cf. Figs. 4, 5 and 6).

When the Sun rose in Auckland on 7 December the weather was not at all promising, but most of the clouds subsequently dispersed and the transit was visible. Messrs Storey and Thielkuhl then obtained a series of seventy-two photographs before further clouds caused these operations to be suspended until just before third contact when two final images were exposed (see Dick, 2003: 267). Meanwhile, Smith and Pritchett successfully timed both egress contacts with the 12.7-cm refractor and a smaller (unspecified) telescope. A newspaper account mentions that "A considerable number of people gathered outside the enclosure, and seemed to take a considerable interest in watching the various observations. Of course it will be several years before the data collected yesterday are so reduced as to give the information sought, but all must feel pleasure to know that the success of the American party of Observers at Auckland has been greater than they anticipated ..." (The transit of Venus. The United States Expedition ..., 1882).

International Expeditions. Burnham: the British Expedition.

After an exchange of letters between Sir George Airy and Dr James Hector, Airy (1880) was moved to comment that "We are now entitled to consider New Zealand as probably the most important country of stations for observations of the Transit of Venus of 1882." and funding was approved to support a further expedition. Initially the Royal Society's British 'Transit Committee' favoured Auckland for the 1882 station, but H. A. Atkinson (1882) vehemently counselled against this, singing the climatic and geographical merits of Napier, if a decision was ultimately made to abandon the 1874 station at Burnham. Eventually

logic prevailed and Burnham was retained, but some of the instruments and all of the personnel assigned to New Zealand on this occasion differed. Head of the party was Lieutenant-Colonel G.L. Tupman, who was assisted by G.E. Coke. Both observed from Burnham – on this occasion there was no ancillary station. For the transit, Tupman used a 15.2-cm (6-in) Cooke refractor and 'chronometer F', and Coke an 11.4-cm (4.5-in) Cooke refractor and a Molyneux chronometer. Assisting Tupman were his wife, a Mr Gill from the Telegraph Department in Wellington and Bombardier Wilson. Coke was also aided by his wife, a Mr White from the N.Z. Telegraph Service and a Mr Hamilton of the *Lyttelton Times*.

The astronomers awoke to a fine windless day on 7 December, and the roofs and eastern sides of the equatorial houses were removed entirely to facilitate easy observation. Prior to third contact, Tupman carefully examined the limb of Venus but could not detect any evidence of an atmosphere: "The limb was absolutely sharp, of striking abruptness. There was no trace of any shadow on the Sun's surface without the planet, or of any light within the planet's disc. I assured myself of this repeatedly during the hour or more that I had little else to do." (Stone, n.d.: 60). Nearly an hour before third contact was scheduled, Tupman used the Airy double-image micrometer to measure the diameter of Venus.

Just over a minute and a half before third contact was scheduled, Tupman's wife began counting seconds aloud, and then "Venus drew pretty quickly up to the Sun's limb. I expected to see the shadow between the limbs sooner than I actually did. The distance became very small without any diminution of the Sun's light ... [then] A faint shadow grew slowly between the limbs." (*ibid.*). This faint shadow was parallel to the limbs, not many seconds of arc in length, and although apparent was certainly difficult to see. Just nine seconds later Tupman reported that "... the Sun's limb had lost its sharpness from the overlapping of Venus' atmosphere ... " and seven seconds later "... the atmosphere was conspicuous, connecting the now formed cusps." (*ibid.*). Upon reviewing his third contact observations, Tupman stated: "The illumination of the planet's atmosphere was, at first, almost as bright as the last glimpse of the Sun's limb, but it was different altogether. It was brightest at the sharp limb of the planet, of a different colour to the Sun's limb, and faded off at its outer border. It was less than a second of arc broad, but might, perhaps, have appeared a little broader had there been no cloud." (*ibid.*). The "cloud" that Tupman alludes to

was nothing more than a hazy white that spread over the Sun prior to third contact but in no way impeded his view of the transit.

Once third contact had been observed, Tupman installed the Airy micrometer and measured the distance between the cusps, and upon replacing the 210 power eyepiece "... again saw the illumination in Venus' atmosphere, but only in the upper or south portion of that part of the planet which was outside the Sun ... It seemed to start from the Sun's limb, and to extend 60° or 70° along the south limb of Venus, about half a second of arc broad, distinctly visible, though faint." (*ibid.*; cf. Fig. 20). In all, visual evidence of Venus' atmosphere lasted for about fifteen minutes. About five minutes later, Tupman obtained a clear view of fourth contact.

Coke also successfully observed the egress contacts. As third contact approached he noticed a "shadow" between the limbs of Venus and the Sun, and although this subsequently became more decided, even at its darkest "... it never approached in the slightest degree to the darkness of the planet; it was never more than a hazy shadow." (Stone, n.d.: 61). But at the time he estimated third contact to take place, Coke could see "... no appearance of an atmosphere of Venus ..." (*ibid.*). He also observed fourth contact without incident, but did not place much faith on the time he recorded.

Government Observers. New Plymouth.

At New Plymouth, T. Humphries, the Chief Surveyor, observed the transit with a 10.2-cm (4-in) Cooke refractor and a chronometer, assisted by T.K. Skinner. The longitude of the site was 11h 36m 17.55s E of Greenwich and the latitude 39° 04′ 0.″8 S. Shortly before third contact Humphries observed that "A dark haze appeared between the limbs, which I thought was going to merge into "black drop", but five seconds [later] ... clear light appeared." (Stone, n.d.: 68).

Government Observers. Wairarapa.

When the Government was planning its transit stations, a decision was made to "... also observe in the Wairarapa district, so as to secure a chance of clear weather on the other side of the Rimutaka range, in case clouds prevail on the Wellington side of the range and obscure the view." (The transit of Venus, 1882b). A site referred to as "Bidwill's", with a longitude of 11h 41m 41.47s E and a latitude of 41° 11′ 29″ S, was selected just south of the town of Martinborough, and quite near to the

observatory maintained by Stephen Carkeek at nearby Featherston (see Orchiston, 2001b). The Chief Surveyor of Wellington, J.H.A. Marchant, was assigned to this temporary transit station, and he used a 10.2-cm (4-in) altazimuth-mounted Browning refractor (loaned by David Gray of Wellington) and a Barraud chronometer. He was assisted by G. Struthers and a Mr Wright. The times of both egress contacts were recorded, and prior to third contact Marchant noted that the limb of Venus "... appeared to be surrounded by a haze." (Stone, n.d.: 54). Just after third contact he observed that "... the rim of the Sun appeared to advance before the outwards limb of Venus, that is to say, it appeared to be pushed out by the black disk of the planet, and the aureole was distinctly visible round the outward rim of Venus." (*ibid.*; cf. Liversidge's drawings in Fig. 20). This feature lasted for some minutes and then disappeared.

The other observer at "Bidwill's" was Captain J.D. Hewitt, R.N., a Palmerston North farmer and amateur astronomer (Seymour, 1985), who used a 21.6-cm (8.5-in) Browning reflector loaned by J.H. Pope, Inspector of Native Schools. This historic telescope was later owned by the Wellington Astronomical Society (see Dodson, 1996). Hewitt timed the fourth contact, but provided no other information about the transit (Stone, n.d.).

Government Observers. Wellington.

In Wellington, 'Mount Cook Observatory' was specifically set up for the transit on what was until recently the site of the National Museum, at longitude = 11h 39m 05.91s E, and latitude = 41° 18′ 0″.6 S (Stone, n.d.: 55). It was "... a plain wooden building externally, but internally is very complete and elaborately fitted up." (Tomorrow's transit of Venus, 1882). Leading the transit party was Charles William Adams from the Survey Department (see Adams, 1993), assisted by Mrs. Adams and W. Holmes, and at their disposal was a 10.6-cm (4.17-in) Solomons refractor (loaned by Mr Barnard of Wellington), a sidereal clock by Dent, and a chronograph. In addition, there was a 7.6-cm (3-in) Troughton and Simms transit telescope (Tomorrow's transit of Venus, 1882) and a "... new zenith telescope of American invention, for determining latitude, has been erected ... and has enabled the latitude also to be precisely ascertained ..." (The transit of Venus, 1882d). Transit day was bright and clear, and the entire egress phase was seen. Since no suitable solar filter could be obtained in time, Adams observed the transit by projecting the image onto a screen. He successfully recorded

the times of the third and fourth contacts but reported that "... there was an almost entire absence of the incidental phenomena that I had been led to expect." (Stone, n.d.: 55). Perhaps this was because of his less than satisfactory observing procedure.

The transit was also observed by James McKerrow, the Surveyor-General of New Zealand (Obituaries, 1920), from Thomas King's observatory in downtown Wellington (with as longitude of 11h 39m 05.57s E, and a latitude of 41° 17′ 14.″3 S). King was a prominent amateur astronomer (Orchiston, 1998c), and his observatory housed a sidereal clock and the recently-acquired 12.7-cm (5-in) equatorially-mounted Grubb refractor which later ended up in the King Edward VII Observatory in the Wellington Botanic Garden (see Seymour, 1995). Assisting McKerrow were Alexander Barron and Thomas Grant, both officers of the Survey Department. McKerrow obtained a "most satisfactory" view of the transit and succeeded in timing both egress contacts. No black drop was observed at third contact, and the fourth contact "... was not marked by any phenomena ..." (Stone, n.d.: 57). In conclusion, McKerrow was moved to comment that "... in the absence of clouds, wind, or other disturbing cause of weather, I cannot conceive of more favourable conditions for the observation." (*ibid.*). Soon after his observation of the transit, McKerrow was elected a Fellow of the Royal Astronomical Society (Obituaries, 1920).

Government Observers. Clyde.

Wellington-based Dr (late Sir) James Hector, Director of the Colonial Observatory, the Geological Survey and the Colonial Museum – among other posts (see Dell, 1990) – selected Clyde in Otago for his transit site because of its "... having an almost continental climate. Rain rarely falls, and a bright still atmosphere is almost invariably experienced at early morning. It was one of the few places in New Zealand that enjoyed a clear sky throughout the whole day of the last transit in 1874. It is also conveniently circumstanced as regards the telegraph system, being the junction point of two separate lines by which communication could be maintained with Burnham observatory." (Hector, 1882: 326). From his viewpoint, it was the ideal site, and circumstances subsequently vindicated this choice.

Hector was furnished with a 12.7-cm (5-in) $f/13$ altazimuth-mounted Newtonian reflector by Cooke (loaned by G.V. Shannon of Wellington), a Russell chronometer, a stop watch and a chronograph. By 22 November the observing station was operational, and on the 24th time

signals were exchanged with the British station at Burnham for the first time. Assisting Hector during the transit were E. Ashcroft, Mr. Henry, the local telegraphist at Clyde, Mr McKay, the district surveyor, and Major Kedell.

The day of the transit dawned cloudy, but cleared prior to third contact. At this time, Hector (1882: 328) noted: "As soon as the last shred of cloud passed, all boiling of the sun's edge cleared, and it was more sharp and steady than I had ever before seen it." This from an experiences astronomical observer. Venus was then near the solar limb, and "No trace of a halo or indefinite outline was seen round the planet ..." (*ibid.*). Unfortunately a small dense cloud intervened and prevented observation of third contact, but soon after the Sun was again visible Hector noticed that

> "... the outline of the emerged limb of the planet suddenly became apparent against the background of space as a delicate violet-tinted streak, having its concave edge sharp but the convex edge discontinuous. I brought this appearance out more distinctly by cutting off the sun's limb with a dense glass. Its extreme width I estimate at about 1-50th of its distance from the sun, which was about the semi-diameter of the planet [cf. Fig. 18]. Suddenly, with a twinkle, this phenomenon disappeared, and I called time at 7h. 42′. This twinkle made a most distinct impression on me. There was not the least vibration at the time and my eye was not fatigued, as I still saw the "rice grains" [= granulation] on the sun's surface." (Hector, 1882: 329).

Nearly nine minutes later, Hector successfully timed the fourth contact.

Independent Observers Back in 1875, Lieutenant Colonel Tupman (head of the 1874 British station at Burnham) observed that "There is already a good deal of private scientific enterprise in New Zealand ... The last Transit will undoubtedly have given a stimulus in the direction of astronomy, and it may be expected that by 1882 there will be many good private telescopes, and amateur observers willing to help in an extensive scheme of observation." This certainly proved to be the case, with private observers scattered the length of the nation.

Independent Observers. Auckland.
In order to observe the transit, the former Chief Surveyor of Auckland Province, Captain Theophilus Heale (Scholefield, 1940: 371–373), used

a 12.7-cm (5-in) equatorially-mounted Cooke refractor (loaned for the occasion) and a chronometer, which he installed in an observatory that he built near his house in the suburb of Parnell. The co-ordinates of this observatory were: longitude = 11h 39m 9.40s E; latitude $36^\circ\, 51'\, 9''\!.5$ S (Stone, n.d.: 72). At sunrise the transit was visible through thin misty clouds, which thickened and prevented him from timing third contact. Soon after, however, the clouds dispersed and "The external contact was, therefore, observed with the greatest accuracy." (The transit of Venus. The United States Expedition ..., 1882).

As we have seen, J.T. Stephenson observed the transit from the U.S. compound in the Auckland Domain, thanks to the intervention of Lieutenant-Colonel Tupman. While he had free access to the time-service maintained by the Americans, Stephenson did use his own telescope, a 16.5-cm (6.5-in) equatorial-mounted reflector with a mirror by Calver (The transit of Venus, 1882d). Light clouds covered the Sun during the egress phase, and he timed the third contact with difficulty. Although observing conditions were far from ideal, he reported that "There was no appearance of the black drop observed, neither was there any appearance of the light surrounding the limb of the planet which observers at previous transits have seen." (The transit of Venus. The United States Expedition ..., 1882). By the end of the transit the Sun was largely free of clouds, and he obtained a reliable time for fourth contact, which was included in Stone's monograph (n.d.: 73).

Professor S.J. Lambert from Auckland University College and Samuel Stuart (see Orchiston, 1998c: 110) were located at Stuart's house on New North Road, and supplied with 7.6-cm (3-in) and 6.35-cm (2.5-in) refractors and an "... instrument fitted up for photographing the transit." Lambert does not describe this last-mentioned instrument, other than to state that its lenses were by Dallmeyer (The transit of Venus. The United States Expedition ..., 1882); it may have been an astrograph, or a Dallmeyer refractor fitted out for prime focus photography. During the transit, Stuart and Lambert successfully obtained a good series of photographs. Prior to third contact, "... nothing peculiar was noticed, except a faint ring of light surrounding the planet [cf. Fig. 18] ... but [there were] no traces of anything appertaining to a satellite ..." (*ibid.*). Both astronomers observed the third contact, but neither of them saw the black drop. Clouds prevented them from witnessing fourth contact.

Thomas Cheeseman was another Auckland amateur who observed the transit, using the "large reflecting telescope" in his observatory in the suburb of Remuera. He did not attempt to obtain accurate

times for the egress contacts, but like Stuart and Lambert he reported the presence of a Venusian atmosphere: "... as the time for internal contact approached it appeared to Mr. Cheeseman as if the outer edge of the sun was bulged out a little just before the contact was actual. The phenomenon may have various explanations, but the more reasonable is probably that as Venus neared the sun's edge the glowing light behind the dark body of the planet shone through the dense atmosphere of Venus, and thus appeared to swell the illuminated edge in front of the dark body of the planet." (The transit of Venus. The United States Expedition ..., 1882).

Independent Observers. Thames.

During the second half of the nineteenth century, John Grigg (Fig. 36) was one of New Zealand's most distinguished amateur astronomers. Not only did he discover a number of comets (Orchiston, 1993), but he was one of those who pioneered astronomical photography in New Zealand (Orchiston, 1995). Although Grigg built two different observatories during his lifetime in the wealthy gold-mining centre of Thames (Orchiston, 2001d), both of these postdated the 1882 transit, for which he fitted out a temporary observing station. A contemporary newspaper reported that "The apparatus was provided by Mr. Grigg and adjusted accurately. Mr. Foy was in attendance to photograph the sun during the transit and Mr. and Mrs. Neill recorded the time of the different occurrences by means of a seconds pendulum in the lower room." (Transit of Venus, 1882). Nowhere is Grigg's "apparatus" described, but we know from slightly later documentation that he possessed an 8.9-cm (3.5-in) Wray refractor with an astrograph and a prime focus camera (Orchiston, 2001c). Foy succeeded in taking two photographs of Venus on the disc of the Sun, but clouds then intervened and prevented him from exposing further plates and Grigg from timing the two egress contacts. The newspaper article reports the reason for this interest in photographically recording the transit: "The pictures were taken in the hope that they might be of use should the operations in other parts fail through any mishap or unfavourable weather ..." (Transit of Venus, 1882).

Another Thames observer was E.W. Hollis, who viewed the transit through what is only described as "... a powerful telescope ..." (*ibid.*). He saw "... an exceedingly beautiful phenomena ... which bears upon the disputed point as to whether Venus possesses an atmosphere. Several times during the transit there appeared on the western edge of

Figure 45. Atkinson's observing station (Courtesy: Dr Harry Atkinson).

the planet a pretty roseate light such as would be deflected only through an atmosphere medium apparently shining between the equator and the north pole." (*ibid.*).

Independent Observers. New Plymouth.

In New Plymouth at a site with a longitude of 11h 36m 17.55s E of Greenwich and a latitude of 39° 03′ 57″ S – about one hundred yards away from the observatory of the Chief Surveyor, T. Humphries – A.O.N. O'Donoghue carried out independent observations of the third contact with a 6-cm (2.375-in) Elliott refractor and a watch. He also failed to detect the black drop, or "... haze of any description at the time of contact." (Stone, n.d.: 69; cf. The transit of Venus. The United States Expedition ..., 1882).

Independent Observers. Wellington.

The only independent Wellington observers mentioned by the newspapers (The transit of Venus. The United States Expedition ..., 1882) as reporting "... thoroughly satisfactory observations of both internal and external contact." were Arthur Stock (Fig. 36) and Thomas King (from Stock's observatory in Thorndon), and Messrs Shannon and Littlejohn (from The Terrace), yet for some reason their observations did not make it into Stone's New Zealand analysis. This is particularly remarkable in the case of Stock and King, as both were experienced amateur observers (see Orchiston, 1998c); at the time, Stock also doubled as the part-time Astronomical Observer at the Government's Colonial Observatory in the Wellington Botanic Garden (Eiby, 1977). Immediately before the transit, Stock wrote: "What is proposed to be done at the Wellington Observatory, Thorndon, is as follows:- Two observers, Mr T. King and Archdeacon Stock, will be stationed there, with two 4-inch telescopes. At the side of each will be two assistants – one with a chronometer, the other to write down what is said by the observer." (Tomorrow's transit of Venus, 1882).

The only other Wellington observation of note is the report that W.B. Gibbs "... has also taken several excellent photographs of the phenomenon in its different stages." (The transit of Venus. The United States Expedition ..., 1882). It is of some regret that the current whereabouts of these – if they have in fact survived – is unknown, as they constitute an important contribution to the early development of astronomical photography in New Zealand (see Orchiston, 1995: 9-12 for an overview of this topic).

Independent Observers. Nelson.

Nelson's leading amateur astronomer was the talented lawyer, Arthur Samuel Atkinson (Porter, 1993), who was furnished with a 10.2-cm (4-in) altazimuth-mounted Browning refractor, a Porthouse chronometer and a stop watch. He was aided by two assistants, one of whom, Maurice Richmond, was at the chronometer. The co-ordinates of their observing station, a small shed erected for the occasion, were: longitude = 11h 33m 08.82s E; latitude = $41^\circ\, 17'\, 01''\!.9$ S. Fig. 45 shows this shed, the telescope, and from left to right, Richmond, Atkinson and the second (unnamed) assistant. On the day of the transit the sky was clear, but "... the Sun's limb [was] considerably agitated, and the planet also, though to a less extent." (Stone, n.d.: 62). However,

Atkinson was convinced that this situation did not interfere with his observations of the egress. He wrote that when third contact was imminent, "... I saw that dark waves, as it were, were carried from her [Venus] across the narrow intervening portion of the Sun's disc to his limb; narrow symmetrical portions of the preceding limb of the planet seemed to detach themselves and advance to the Sun's limb, and then pass away." (Stone, n.d.: 63). Atkinson judged third contact to occur when these dark waves "... suddenly adhered, as it were, to the Sun's limb ..." instead of disappearing. He then found – to his great surprise – that although Venus' image was clear and undistorted, "... it was not apparently the whole planet that was adherent to the Sun's limb, but a large detached segment of it ... I turned my attention to the dividing light at its thinnest part. The *apparent planet* seemed to press upward and curve in; the chord of the segment and the two bodies were apparently touching along a considerable part of the segment, but for a very faint white line between them, though it looked more as if this line were marking their junction than separating them." (*ibid.*). The faint white line persisted for more than a minute before disappearing. Atkinson then saw "... the upper limb of the segment clearly protuberant above the line of the Sun's limb, its contour marked by a very faint line of grey light, and separating the Sun's cusps by a considerable interval ..." (*ibid.*), which he estimated at about one-third of the planet's diameter. He noted that when Venus was about one-third of her diameter off the Sun, "... the part still on the Sun was evidently distorted, being somewhat pear-shaped ... " (*ibid.*). He subsequently watched the fourth contact.

Independent Observers. Christchurch.

Mr Townsend's observatory was the site of Christchurch's assault on the transit, with the surveyor Walter Kitson (from the Lands and Survey Office) making use of the 15.2-cm (6-in) equatorially-mounted Cooke refractor (Fig. 46) and a chronometer, while Townsend himself used his 8.6-cm (3.375-in) Dallmeyer equatorial and a stop watch. During the morning the sky was covered by light cirrus cloud, but in spite of this both observers saw the transit and timed the two egress contacts.

Kitson specifically looked for signs of a Venusian atmosphere, but "... no halo nor any light at all different from the light of the Sun was visible round the planet, not was there any shadow round the planet's limb." (Stone, n.d.: 58). What he did notice, though, was that Venus "... appeared to have a lighter tinge towards its limb. This light tinge

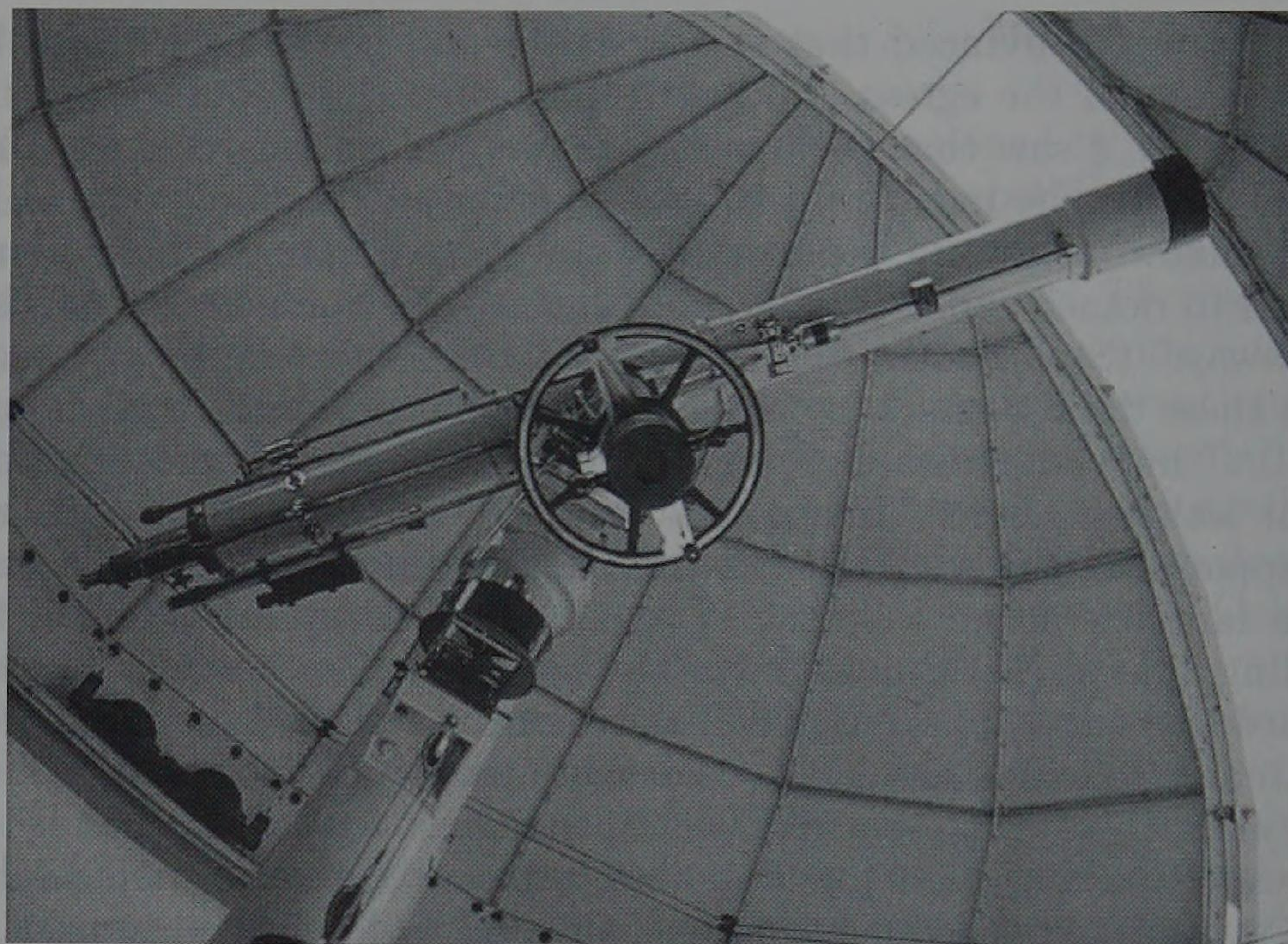

Figure 46. Townsend's 15.2-cm Cooke refractor (after Tobin and Evans, 1996: back cover).

began to displace the blackness of the centre at about one-tenth of the planet's diameter from the edge. The tinge was of a bluish colour, the centre being almost black." (*ibid.*). About ten second before third contact, Kitson recorded "... the first appearance to me of a shadow or darkening of the Sun's face between the limbs of the planet and Sun near the point of contact." (*ibid.*), and third contact subsequently occurred, without any sign of the notorious 'black drop'. About twenty minutes later Kitson observed fourth contact.

Townsend provides an extremely brief account of his observation of the transit, although this does include times for the third and fourth contacts. He noted that "Part of outline of Venus seen till 12 minutes after internal contact, outside limb of Sun. Centre of planet when on the Sun quite black, margin for one-third diameter indigo ... No markings or light seen on body of Venus." (Stone, n.d.: 59).

Independent Observers. Dunedin.

The talented Arthur Beverly (Fig. 47) so impressed Colonel Tupman that he was moved to write John Tebbutt in the following terms:

> "Since I have been in this wonderful country I have discovered "a truly bright light under a bushel" in the person of Mr. Arthur Beverley [sic.] of Dunedin. Like many distinguished Astronomers he is a mechanic of a high order, making his own microscope objectives on his own formulae; inventing ingenious apparatus and possessing high mathematical attainment's. In Europe he would be in the first rank among physicists & Astronomers. In New Zealand scarcely anyone knows his name not one soul knows his merits. A watchmaker, I think, by trade, from an obscure part of Scotland, with consumption and another about as deadly disease, he made achromatic doublets of surpassing excellence for Sir David Brewster, Prof Thwaites & other distinguished men until he was able to pay his passage to New Zealand. There he soon saved as much as he required, or acquired enough somehow, chiefly by plying his trade, and at once gave up business to live & revel in botany, physics & astronomy. He quickly gets out the orbit of any comet that he sees and probably was the first to find that of the present comet ...
>
> It is right that you should know what a neighbour you have. He only possesses a three inch achromatic, but it is very good and very well mounted equatorially, with circles graduated to 3′... [and] an excellent chronometer ..." (Tupman, 1883; cf. Campbell, 2001b; Gillies, 1881).

Beverly's observatory was located at longitude of 11h 22m 02.18s E and latitude 45° 52′ 20″ S, and apart from the afore-mentioned small equatorially-mounted telescope housed an Arnold and Dent chronometer. Beverly used these facilities to observe the transit and record the two egress contacts, and as third contact approached he noted that "... the thread of light separating the limbs of the Sun and Venus, having become excessively slender, appeared to part or darken rather suddenly at the point of contact. No appearance of ligament or anything anomalous." (Stone, n.d.: 65). Seven seconds later "... a very faint ruddy line begins to appear between the cusps ...", (*ibid.*), and eighteen seconds later he noticed that the ruddy line had become "... more distinct, longer and sensibly arched." (*ibid.*). Fourth contact was observed without incident, and after the transit Beverly summarised his impressions: "There was nothing of a prolonged or doubtful character about the phenomena at internal contact such as we were led to

expect ... The luminous thread became gradually thinner and finer as the planet advanced, until it was clearly obliterated ... Possibly the pink line joining the cusps might have been a second or two sooner had I been on the look out for it." (*ibid.*). But elsewhere, he presents a somewhat different perspective:

> "In about ten seconds after [third] contact the only other phenomena worth mentioning began to appear. The part of Venus which projected beyond the sun's disc showed a very fine pink outline [cf. Fig. 30], caused no doubt by sun light refracted through the atmosphere, which continued visible until the disc of Venus projected about a fifth of its diameter beyond the solar disc. It then gave way at the north side, but continued visible at the south side until Venus was half off, when it appeared like a minute pink hair standing perpendicular to the sun's margin at the edge of the same circular notch." (The transit of Venus. The United States Expedition ..., 1882).

A second Dunedin amateur observer was Robert Gillies, a former trigonometrical and geodesical surveyor (Gillies, 1881), and he was assisted during the transit observations by a Mr. Keys. Gillies' observatory was sited near Beverly's home at effectively the same latitude and longitude, and it housed an astronomical clock, a chronometer, a chronograph and a 15.2-cm (6-in) equatorially-mounted refractor that Tupman examined and found to exhibit considerable spherical aberration (Stone, n.d.: 67). Despite this shortcoming, Gillies observed the third contact under clear skies, and about two seconds later he noticed that "... there was a faint grey light on Venus." (Stone, n.d.: 66). As fourth contact approached, he noted that Venus "... seemed to appear to draw out towards the limb into a pear shape, and I drew Mr. Keys' attention to it ..." (*ibid.*). By the time of fourth contact the viewing conditions were not so favourable, and Gillies had some doubts about the contact time he recorded. After the transit, he wrote that during his observations "... there always was a sort of radiance or faint light in front of the planet, which now, I have no doubt, was the atmosphere of Venus ... it was this faint light that I saw distinctly beyond the line of the disk of the Sun, and which in my report I call the limb of Venus. At the time I thought it was the planet itself, slightly illuminated. I think now it must have been its atmosphere ..." (*ibid.*).

Henry Skey (Fig. 47) was one of New Zealand's most experienced amateur astronomers (Campbell, 2001a), and he observed the transit

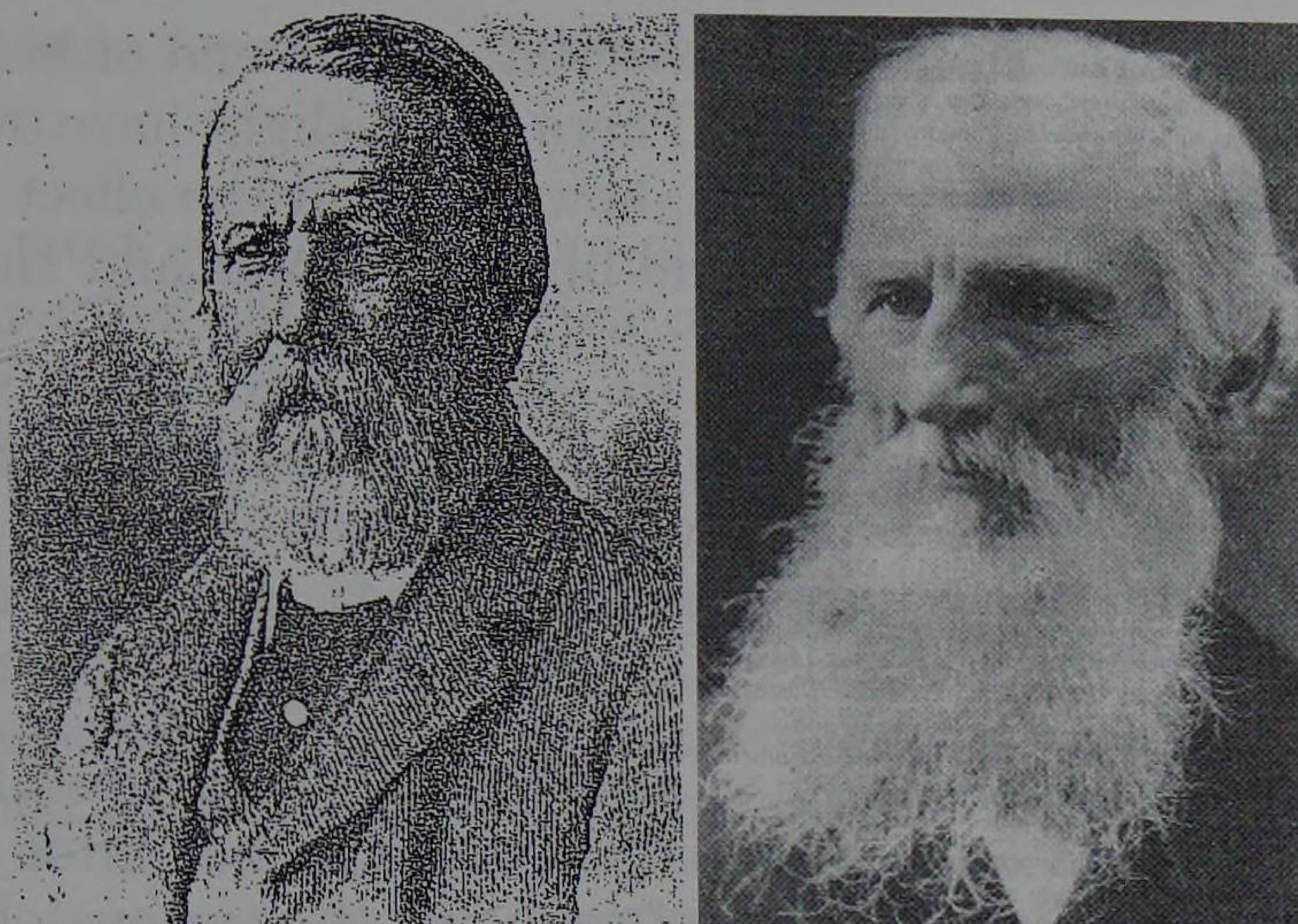

Figure 47. Left: Arthur Beverly (Courtesy: Robert Campbell). Right: Henry Skey (Courtesy: Otago Early Settlers Museum, Dunedin).

from his observatory in suburban Dunedin (longitude = 11h 21m 58.08s E; latitude = 45° 52′ 11″ S) with the 23.5-cm (9.25-in) Browning reflector that is now at Ashburton College (Evans and Lucas, 1989). Contact times were recorded by A.H. Ross, using a Porthouse chronometer and by J.K. Logan with reference to the observatory's astronomical clock. At 08h 00m 50.9s GMT, immediately before third contact, Skey observed that "... the limbs of the Sun and Venus seemed to make a vibratory approach towards each other, for the extremely thin thread of light broke, and then joined again four or five times; in other words, thin pointed and well-defined cusps kept forming and then joining." (Stone, n.d.: 67). This lasted about three seconds, then "... a straw coloured shade was observed on the previously white disc of the Sun between the limbs of the Sun and Venus, which rapidly passed through a brown to a nearly black shade, and completely obscured the Sun's limb." (*ibid.*). Skey noted that "The ligament arising from this contact [i.e. third contact] was of the same shade of darkness as the body of Venus and the background of the sky, that is, nearly black, and no change in this colour was afterwards observed in any part of the ligament. The cusps at this time were now blunted, and, when the leading limb of Venus was well off the Sun's disc, the points of the cusps were cut off by straight shaded lines. *No "black drop" was observed, nor did Venus ever assume a "pear shape."* (*ibid.*; my italics). Nearly 21

minutes later fourth contact was observed. At the end of his account of the transit Skey pointed out that "There was a slight haze over the Sun during these observations ... This, however, had the effect of wonderfully improving the definition of the limbs of Venus and the Sun ..." (Stone, n.d.: 67).

4. Discussion

Organizing the various Australian and New Zealand transit programs in 1874 and 1882 was a major logistical exercise, but after the transit came the equally challenging task of reducing the various observations and deriving meaningful values for the solar parallax.

The overall Australian transit program in 1874 was a resounding success. According to one Sydney newspaper, the transit observations arranged by Russell "... far exceeded expectations. In fact, when the Astronomer Royal issued his report, it was shown that if England had not sent her observing parties to the South Seas, but had relied on New South Wales, exactly the same solar parallax would have been found as that obtained from all other stations." (Mr. H.C. Russell ..., 1880). This same newspaper also proudly claimed that "The photographs taken in this colony were the best and most numerous obtained by any country ... in the space of three hours New South Wales secured 1300 photos. of Venus on the Sun's disc." (*ibid.*).

In 1875, both Ellery and Russell journeyed to England, ostensibly to report personally to Airy on the Melbourne and Sydney Observatory transit programs, and to hand over their observations. These included 164 photographs taken at the Sydney transit stations (Russell, 1876). For his part, Todd (1875) had to be content with posting the Adelaide Observatory results to Airy. It is of interest to note that the New South Wales, Victorian and South Australian Governments all provided Airy with financial contributions towards the reduction costs of their respective observations (see Airy, 1878a, 1878b, 1879).

The end result of these endeavours was a paper penned by G.L. Tupman that appeared in an 1878 issue of *Monthly Notices of the Royal Astronomical Society*. This contained the contact times reported by the various Adelaide, Melbourne and Sydney Observatory transit station observers, and by six independent Australian observers: Allerding (Sydney), Dobbie (Adelaide), Singleton (Adelaide), Smeaton (Adelaide), Tebbutt (Windsor) and Wright (Sydney). Tupman treated the ingress

and egress times separately, and in his initial discussion he outlined his strategy:

> "The most satisfactory way perhaps to treat the *Ingress* is to rely upon the observation of the brightening or clearing of the dusky light seen by all observers between the limbs after the circular form of the Sun's limb was restored. With some of the smaller instruments, no doubt in some degree depending upon the colour and intensity of the absorbing media employed, this brightening occupied a very long time, but generally in the larger instruments the uncertainty was confined to less than 10s." (Tupman, 1878: 447–448).

Tupman identified twenty different observers from around the world whose values for the second ingress contact were used in determining a value of $8''.845$ for the solar parallax. Seven of these (35%) were Australians, and their residuals and rankings are listed below in Table 1. The ranking scale (see the third column) ranges from 0 = lowest weight to 2 = maximal weight. In addition to those listed in Table 1, Allerding, Gilbert, Lenehan, Liversidge, Morris, Vessey and Wright all made the initial cut, but with rankings in each case of 0, they all were eliminated for the final analysis.

Australian observers fared similarly in Tupman's analysis of the first egress contact, which produced a vale for the solar parallax of $8''.894$. Ten Australian observers (29% of all observers) featured in his final listing (see Table 2); those who figured in his initial analysis but did not make the final cut were Allerding, Dobbie, Lenehan, Smeaton, Wilson, Wright, and – surprise, surprise – Sydney Observatory Director and program co-ordinator, Henry Russell. Although this parallax value is remarkably consistent with the figure obtained from the ingress analysis, Tupman (1878: 454) pointed out that it "... satisfies very well a majority of the observations, but it makes the Cape times appear 10^{s} and the Sydney 17^{s} late. Such a parallax ... therefore appears improbable." His final evaluation is equally disconcerting:

> "Although the above results of Ingress and Egress present an unexpected agreement, it cannot be said that the mean $8''.8455$ is entitled to much confidence, since all the observations would be fairly well satisfied by any mean solar parallax between $8''.82$ and $8''.88$. $8''.8455$ corresponds to a mean distance of the Sun of 92,400,000 British statute miles." (Tupman, 1878: 455).

Tupman concludes his long paper with comments on previously-published papers and reports about the British 1874 transit observations, where he is openly critical of Airy's "Parliamentary Report", other reports, and a paper published by Stone. He cautions:

> "In commencing an investigation of the parallax from these and similar observations, some selection of phases, depending on the observer's language and on the mutual agreement of observers not very far apart, must be made. Any selection of times made *after an investigation of the effects of parallax*, such as that I have now made, will always expose the result to the suspicion of having been "doctored."" (Tupman, 1878: 456; his italics).

In the final analysis, the British transit observations of 1874, "... only enable us to determine that the solar parallax probably lies between the values of 8.″82 and 8.″88 ... (*ibid.*).

While this must have been disappointing news for Airy, who was almost certainly hoping for a more definitive result, it was consistent with the values obtained by the Americans and the Germans, in part on the basis of observations made in Australia and New Zealand.

The Americans relied for their result on the photographic observations, and the task of measuring the plates obtained at the eight different 1874 transit stations fell to William Harkness. Although these plates yielded "excellent results" for the interval when Venus was on the Sun's disk, photographs of the ingress and egress were of "no value", because of the black drop effect (Harkness, 1883). Measurements of all of the American photographs were completed by the end of 1877, and then came the laborious task of establishing the longitudes of the transit stations. When this was accomplished the official report of the 1874 American transit program was to have been published in a succession of volumes, but funding restrictions only allowed the appearance of the first of these (Newcomb, 1880). Unfortunately, this contained none of the results, as these were planned for subsequent volumes. Further delays ensued, and in the end it was D.P. Todd (from the Nautical Almanac Office) who published a provisional American value of $8''.883 \pm 0.034$ (Todd, 1881). Australian and New Zealand transit stations played an important role in contributing to this result: 46% of the photographs used in deriving this solar parallax came collectively from Hobart, Campbell Town, Queenstown and the Chatham Islands (see Table ??). Nonetheless, Todd's result remained contentious, because of certain concerns about the quality of the photographic images.

Table 1. Australian observers featuring in Tupman's final ingress (left) and egress (right) analysis (residuals in seconds).

Observer	Residual	Ranking	Observer	Residual	Ranking
Ellery	–1.0	2	Ellery	+0.7	2
Russell	+ 1.1	2	Tebbutt	–4.1	2
Scott	+7.5	2	Todd	–2.9	2
Tebbutt	–12.1	2	Vessey	+1.6	2
Macdonnell	+1.5	1	Hixson	–7.0	1
White	–0.9	1	Liversidge	+0.2	1
Wilson	+7.8	1	Moerlin	–3.4	1
			Singleton	+4.2	1
			Tornaghi	–4.9	1
			White	+5.4	1

These showed some limb-darkening, and there was also a difficulty in establishing plate scales (see Lankford, 1984).

Table 2. Photographs from 1874 American transit stations used in deriving a value for the solar parallax (adapted from Dick et. al., 1998).

Station	Number	% of Total
Vladivostok (Russia)	13	3.71
Nagasaki (Japan)	60	17.14
Peking (China)	90	25.71
Kerguelen Island (Indian Ocean)	26	7.43
Campbell Town (Australia)	55	15.71
Hobart (Australia)	39	11.14
Queenstown (New Zealand)	59	16.86
Chatham Islands (New Zealand)	8	2.29
Total	350	99.99

The German results for the 1874 transit rested upon photographic observations made at six different locations, of which the Auckland Island station was but one. In contrast to the American result, the over-

all Australasian contribution to the German parallax values was not so prominent. Duerbeck (2004: 15) has recounted how German Transit of Venus Commission President, Arthur Auwers, was responsible for editing six different volumes, totalling 3,600 pages, which were published between 1887 and 1898. These contained

> "... instructions, reports, measurements, reductions, and finally the overall results of the project. Auwers painstakingly presented the complete material, even including uncomplimentary remarks by expedition members ... [He] painstakingly analysed all observations, visual contacts, photographic positions, and heliometer settings."

The final result? There were two of them: a parallax of $8''.810 \pm 0.120$ based on photographic observations made at four stations (one of which was on Auckland Island), and a value of $8''.8796 \pm 0.0320$ based on a detailed analysis of all heliometer observations (Auwers, 1888). Duerbeck (2004: 16) notes that the more accurate heliometer observations "... suffered from uncorrected systematic errors (which were overlooked even by diligent Auwers), the cause [of which] is difficult to establish today."

In 1882, Australia and New Zealand also played a vital role in providing observations that yielded further solar parallax values. One local newspaper reported with considerable pride that "... now that the transit is past, it is pleasant to reflect that a very large measure of success has been achieved, especially in New Zealand ... and those in Australia have also had a very fair measure of success." (The transit of Venus. The United States Expedition ..., 1882).

All of the 'British' observations were brought together in a monograph by Stone (n.d.), where solar parallaxes of $8''.827 \pm 0.051$ and $8''.882 \pm 0.045$ were derived for the first egress contact. These values were based on observations by thirty different observers, seventeen of whom (56.7%) were based in Australia or New Zealand (see Table ??).

Stone also obtained a figure of $8''.942 \pm 0.047$ for the solar parallax based upon observations of the second egress contact. Of the thirty different astronomers who contributed observations, sixteen (53.3%) were based in Australia or New Zealand, and these are also listed in Table ??.

In 1882, only one US transit station was sited in Australia or New Zealand (in Auckland, New Zealand), and this contributed in a relatively minor way to the resulting solar parallax value derived from

Table 3. Australian and New Zealand observers featuring in Stone's first and second egress contact analyses.

Observer		Resid. 8″.827	Resid. 8″.882	Observer		Resid. 8″.942
Atkinson	NZ	+0.303	–0.444	Atkinson	NZ	–0.101
Beverly	NZ	–0.101	+0.503	Beverly	NZ	+0.914
Coke	NZ	–0.302	–0.619	Ellery	Au	–0.414
Ellery	Au	+1.155	+0.912	Gilbert	Au	–0.925
Gilbert	Au	+1.243	+0.474	Gillies	NZ	–0.820
Gillies	NZ	–0.351	–1.098	Heale	NZ	–0.134
Humphries	NZ	+0.592	–0.155	Hewitt	NZ	–0.549
King	NZ	–2.230	+1.373	King	NZ	–1.041
Kitson	NZ	–0.782	–0.377	Kitson	NZ	–0.554
McKerrow	NZ	–0.203	–0.152	McKerrow	NZ	+0.558
Marchant	NZ	+0.592	+0.418	Marchant	NZ	–0.078
O'Donahoe	NZ	+0.420	–0.327	Skey	NZ	+0.154
Skey	NZ	–0.937	–1.684	Todd	Au	+0.479
Todd	Au	+0.217	+1.698	Townsend	NZ	+0.561
Townsend	NZ	+0.016	+0.047	Tupman	NZ	+0.915
Tupman	NZ	–0.587	–0.861	White	Au	+0.621
White	Au	+0.826	+0.062			

all transit stations. Of the 345 measurable plates taken at the four US and four foreign transit stations, only 31 (a mere 2.7%) came from the New Zealand transit station (Table ??).

Primarily because of the better weather encountered worldwide there were large numbers of successful photographs, so "If ever the transits of Venus could be made successfully to yield the solar parallax, it was now." (Dick et al., 1998: 245). This task fell to William Harkness, and by August 1884 all the photographs had been reduced, but this was merely the first step in a long and tedious process that involved measurements of time and latitude for each station, determination of plate scales, and many other calculations. Finally, on 11 October 1888 Harkness (1888) announced a figure of 8″.847 ± 0.012, and the following year he revised this to 8″.842 ± 0.0118 (Harkness, 188), which corresponds to a mean Earth-Sun distance of 92,455,000 miles.

Part of the problem faced by those who reduced the 1874 and 1882 transit observations was to determine which of the reported ingress

Table 4. Photographs from American 1882 transit stations used in deriving a value for the solar parallax (adapted from Dick et. al., 1998).

Station	Number	% of Total
Auckland (New Zealand)	31	2.71
Cedar Keys (USA)	165	14.45
Cerro Roblero (USA)	216	18.91
San Antonio (USA)	121	10.60
Santa Cruz (Patagonia)	204	17.86
Santiago (Chile)	152	13.31
Washington (USA)	53	4.64
Wellington (South Africa)	200	17.51
Total	1142	99.99

and egress phenomena corresponded to the different contacts. Many observers had spent long hours religiously observing dry runs of the up-coming transits with the aid of artificial transit devices, and when it came to the notorious black drop and other anticipated phenomena they knew precisely what to expect. But for many the 'real thing' proved somewhat of a challenge and some of the phenomena observed were totally unexpected and ran counter to their well-drilled pre-transit practice observations. Some observers also had false expectations based upon what they had read of earlier transits, whilst after the event others went so far as to query their own observations because these apparently did not tally with the 'real' sequence of ingress and egress events as observed (and therefore dictated) by their perceived role-models. One of these was Sydney Observatory's Henry Lenehan, an experienced observer who fancied he saw the back drop in 1874, but since his Director, Henry Russell (1883: 51), saw nothing of the sort Lenehan (1882:54) obviously "... was mistaken ..." Other examples of this kind, particularly relating to Sydney and Melbourne Observatory transit observers, could be cited. Bias in one form or another was obviously incorporated into the records of some observers.

With this caveat in mind, precisely what phenomena were seen by Australian and New Zealand at ingress and/or egress in 1874 and 1882? The most widely-reported phenomenon was the illumination of that section of the Venusian limb that was off the Sun during ingress or egress.

Sometimes the entire limb was lit, while at other times only an arc of it was illuminated. This feature was reported by about thirty different Australian and New Zealand astronomers. Some (e.g. Beverly, Biggs, Ellery, Lenehan, Morris, Russell, Tebbutt, Todd, Tupman, White and Wright) were very experienced astronomical observers, whilst others were relative novices. Both reflectors and refractors were implicated, and these ranged widely in aperture. Analysis of the various observations and observers revealed no obvious patterns or trends. Some observers reported that with the passage of time the illuminated limb was variable in width, while at egress others noted that it was sometimes accompanied by a "polar spot" that persisted after the illumination disappeared. Various observers attributed this limb illumination to an atmosphere of Venus.

A much rarer phenomenon was the reported presence of a broad halo around Venus, visible only when the planet was on the Sun's disk. In 1874 this was noted by Hirst, Lenehan and Macdonnell, all talented and experienced visual observers who used refractors of comparable aperture (10.2–10.8 cm).

Despite Russell's negative result, the black drop *was* indeed observed in 1874, being reported (or accurately described) by Allerding, Belfield, Bolding, Ellery, Gilbert, Hirst, Lambert, Lenehan, Park, Seeliger, Tebbutt, and Wollfram. Ellery, Hirst, Lambert, Lenehan, Seeliger, Tebbutt and Wolfram were all experienced observers, and could not have mistaken what they saw – and reported. Instruments used in making these observations were refractors ranging in aperture from 3.8 to 20.3 cm, and a 7.6 cm heliometer. Once again, no consistent pattern or trend is apparent, and the suggestion (Ashbrook, 1984: 230) that the black drop tended to be associated with small telescopes and low magnifications certainly does not hold up to scrutiny in this instance. The cause of the black drop effect has been hotly debated for more than a century, but it was only comparatively recently that Schaefer (2001: 334) critically evaluated the competing explanations and came up with the correct interpretation:

> "... the ideal image (a circular Venusian disk silhouetted against the Sun) will suffer smearing (from many physical mechanisms) that will produce a somewhat fuzzy image with contour lines (i.e., what is perceived as the edge) that are shaped like the Black Drop. The primary causes of smearing are the usual astronomical seeing (associated with small angle scattering in our Earth's atmosphere) and

Table 5. Solar parallax determinations (adapted, in part, from Dick et al., 1998: 223).

Publ. Date	Observer	Transit(s) or Method	Parallax (″)
1878	Tupman	1874 (British)	8.82 – 8.88
1881	Todd	1874 (American)	8.883 ± 0.034
1888	Auwers	1874 (German)	8.810 ± 0.120
1888	Auwers	1874 (German)	8.8796 ± 0.0320
1889	Harkness	1882 (American)	8.842 ± 0.0118
No date	Stone	1882 (British)	8.827 ± 0.051
No date	Stone	1882 (British)	8.882 ± 0.045
No date	Stone	1882 (British)	8.942 ± 0.047
1891	Newcomb	1761 + 1769	8.79 ± 0.051
1894	Harkness	System of constants	8.809 ± 0.00567
1895	Newcomb	1874 + 1882	8.857 ± 0.023
1895	Newcomb	1761 + 1769 + 1874 + 1882	8.794 ± 0.018
1895	Newcomb	System of constants	8.800 ± 0.0038
1976	[IAU]	Radar	8.794148 ± 0.000007

the usual diffraction in the telescope (the Airy pattern). Other contributing smearing mechanisms that generally do not dominate are imperfections in the telescope's optics, imperfections in the observer's eyes, the finite angular resolution of the detector, and even the physical size of the telescope's aperture."

5. Concluding Remarks

The two nineteenth century transits of Venus marked the end of one astronomical era and the birth of another. They were the last transits used in a serious attempt to resolve the solar parallax problem, before other methods gained favour. They also marked the first internationally-co-ordinated assault on a major astronomical problem using the emerging technology of photography. Photography and its investigative 'handmaiden', spectroscopy, would quickly become the indispensable tools of the "new astronomy", *astrophysics.*

Because of their fortuitous longitudinal positions on the globe and their southerly latitudes, Australia and New Zealand played key roles in the international transit efforts of 1874 and 1882. However, the resulting solar parallax values (see Table 7) differ significantly from the currently-accepted value of 8.″794148 ± 0.000007, which is based upon

radar observations of Venus and was approved by the IAU in 1976. It was only in the 1890s that solar parallax figures that were consistent with the current value emerged, and only when Newcomb and Harkness revisited all of the eighteenth and nineteenth century transit results and also considered an alternative approach to the problem involving the system of constants.

Acknowledgments. I wish to thank Dr Harry Atkinson (Oxford); Robert Campbell (Oamaru, NZ); Peter Hingley (RAS Library); Dr Nick Lomb (Sydney Observatory); Tony Marshall (Tasmaniana Library, State Library of Tasmania); Adam Perkins (RGO Archives, Cambridge); Jackie St. George (Sydney); staff at the Alexander Turnbull Library (Wellington), the Mitchell Library (Sydney), the Queen Victoria Museum and Art Gallery (Launceston) and the Tasmanian Museum and Art Gallery (Hobart); and especially Professor Hilmar Duerbeck (Vrije Universiteit Brussel), for their assistance. I am also indebted to the Donovan Astronomical Trust for providing a travel grant that made the UK-based archival research possible. Finally, I am grateful to Dr Harry Atkinson (Oxford), the Agfa Photo-Historama (Cologne), the Alexander Turnbull Library (Wellington, New Zealand), the Hocken Library (Dunedin, New Zealand), the Krone-Sammlung (Technische Universität, Dresden), Dr Nick Lomb; the Mitchell Library (State Library of New South Wales, Sydney), the Otago Early Settlers Museum (Dunedin), the Queen Victoria Museum and Art Gallery (Launceston, Tasmania), the RAS Library (London), the State Library of South Australia (Adelaide) and the Tasmanian Museum and Art Gallery (Hobart) for permission to publish Figs. 3, 7, 8, 10, 11, 19, 27, 28, 32, 35, 37, 38, 40, 41, 42, 43, 44, 45 and 47.

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ASTRONOMICAL HERITAGES: Astronomical Archives and Historic Transits of Venus
Journal of Astronomical Data, Vol. 10, 7, 2004
Christiaan Sterken, Hilmar W. Duerbeck, eds.

Jean-Charles Houzeau and the 1882 Belgian Transit of Venus Expeditions

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Abstract

In 1871, the Belgian astronomer Jean-Charles Houzeau developed a new approach to determine the solar parallax. His "heliometer with unequal focal lengths" produces a large and a small solar image, as well as a large and small image of Venus. Making the small solar and the large Venus image coincide yields a measure of the distance of the centers of both objects. Two such instruments were build. After being appointed director of the Royal Observatory of Belgium in 1876, Houzeau obtained support to organize two Belgian expeditions to observe the Venus transit of December 6, 1882: one to San Antonio, Texas, and another one to Santiago de Chile. That enterprise was the first major expedition in the history of Belgian science. This paper describes the expeditions, gives some biographical information about the team members, and clarifies the principal instrument and its present-day whereabouts.

1. Jean-Charles Houzeau (1820–1888)

Jean-Charles Houzeau de Lehaie (Fig. 1) became a prodigious writer on scientific and social topics already at an early age. For a while, he lived and studied in Paris, but in 1848, Adolphe Quételet, founder of the

Royal Observatory of Belgium, accepted him first as a volunteer, then as a paid assistant. During the social upheavals of 1848, Houzeau took a firm republican stand and had to resign his post, to leave Belgium and to range about Europe, working in various libraries and writing books on geography. In 1854 he was recalled to Belgium to do work on the triangulation of the Kingdom of Belgium, but when this project was interrupted in 1857 for several years, he left to New Orleans, in vain search for his revolutionary dream of freedom. His first visit to San Antonio, Texas, took place in May 1858, where he stayed till 1862, interrupted by almost a year of surveying work in a region south of Dallas. When the Civil War broke out, he crossed the Mexican border in March 1862. After his return to New Orleans, he served as one of the editors of the newspapers *Union* and *Tribune*, which were mainly read by Afro-Americans. He ran into trouble due to publications such as *The white terror in Texas*, because of his loyalty with the slaves, his advocacy for black civil rights and his refusal to join the confederate army. In March 1868 he definitively left New Orleans, and in June he settled in Jamaica. Here he cultivated a plantation, founded a school for the young natives, and carried out studies in natural sciences and astronomy, mainly for his "Uranographie Générale", for whose observations he also travelled, in late 1875, to Panama.

Jean-Charles Houzeau was a very special person with a most unusual blend of characteristics: an outspoken anti-royalist with very focused political ideas displaying revolutionary attitudes, a peripatetic teacher and at the same time a scientist who severely criticised the paucity of high-precision observations collected at the Royal Observatory of Brussels in his days. His life as an observer covered astronomy, geography, geodesy and natural sciences – not only in Belgium but also abroad.

His travels abroad led to very significant scientific production, in the first place his most homogeneous and extensive star atlas (6000 stars to declination $-65°$) which was made in very good atmospheric conditions by one and only one observer, totally independent from previously published catalogues. His major works include *Vade-mecum de l'Astronome*, the *Uranometrie Générale* and his monumental *Bibliographie Générale de l'Astronomie*, an early precursor of our modern web-based ADS (NASA Astrophysics Data System).

When Adolphe Quételet died in 1874, King Leopold II overrode objections of his ministers and appointed Houzeau to become director of the Royal Observatory – Houzeau was about the only candidate with a vast publication record and broad observational expertise. Houzeau

took his post in June 1876 and was deeply involved in the reorganization and relocation of the Royal Observatory to the suburb of Uccle/Ukkel. He resigned from the post of director at the end of 1883, but continued to work on his voluminous astronomical bibliography. In July 1888, he died from the consequences of malaria that he had contracted more than twelve years earlier.

Extensive biographical notes on Houzeau are available – a monumental one by Houzeau's collaborator Lancaster (1887), others by Rankin (1984) and Evans (1990), and a very recent detailed study by Verhas (2002).

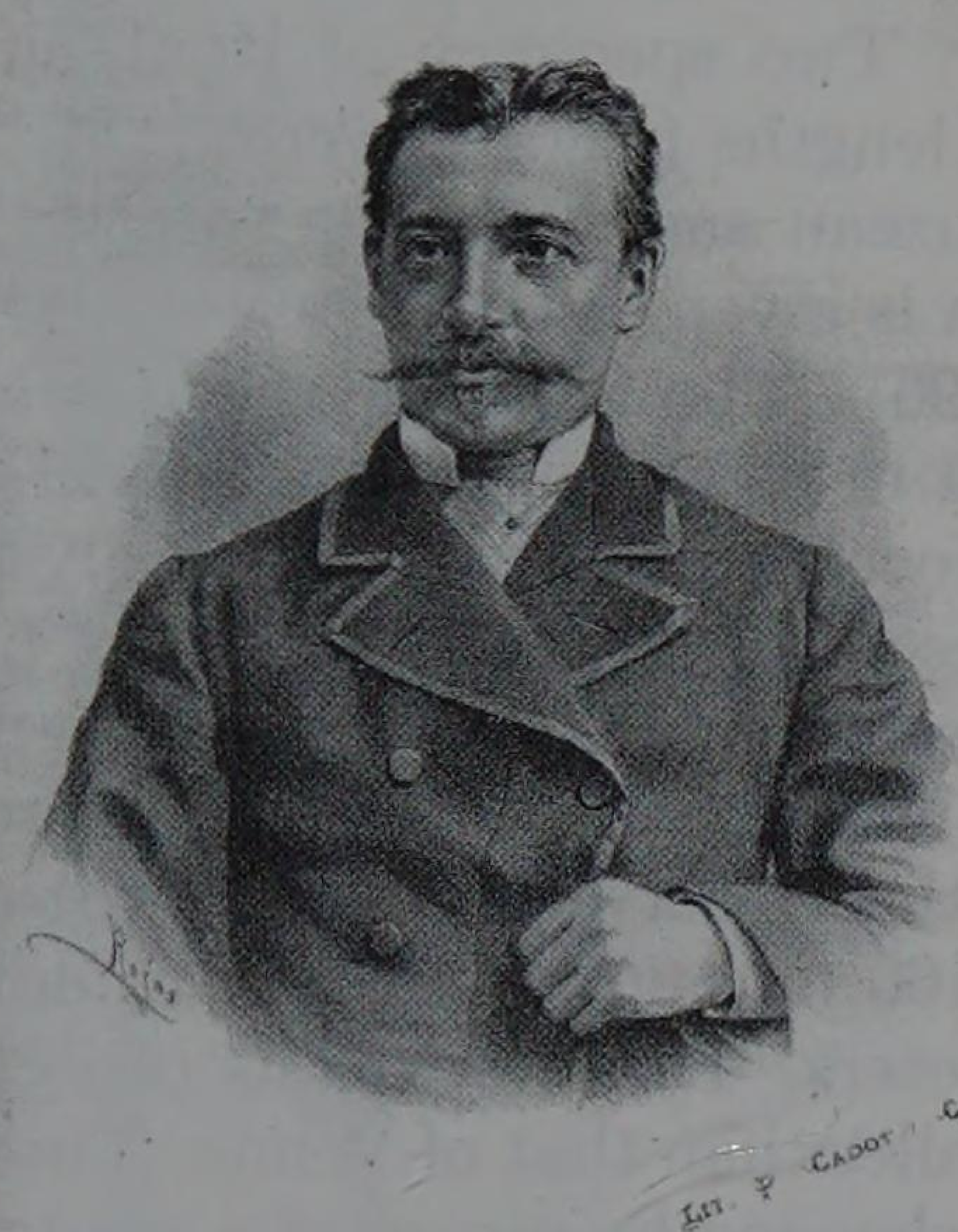


Figure 1. *Left*: Portrait of Houzeau (from Lancaster 1887). *Right*: Louis Niesten; drawing at the time of his Chilean mission (from Zegers 1883).

2. The Principal Instruments

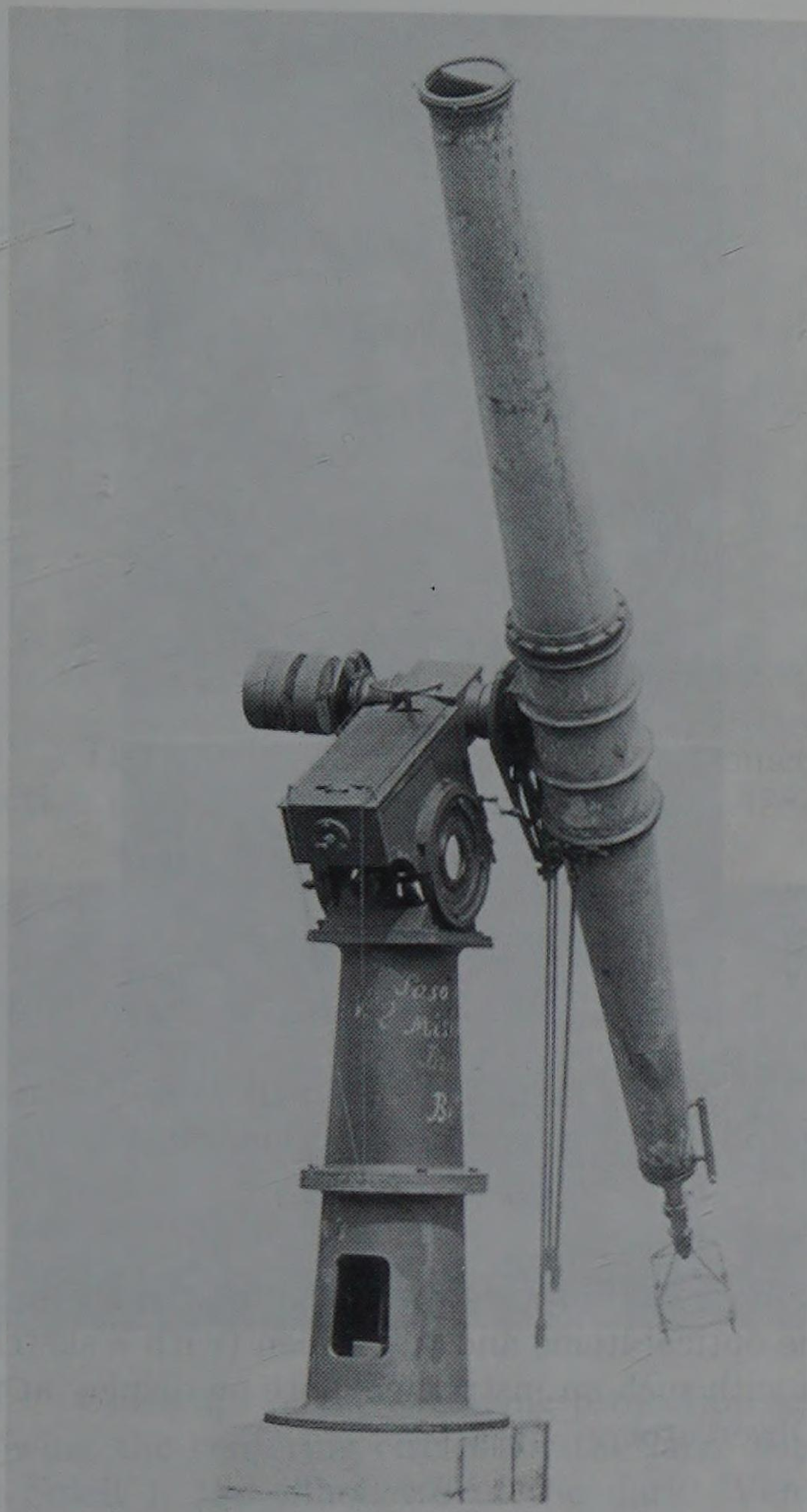
In 1871, the Bulletin of the Belgian Academy of Sciences included a note by Jean-Charles Houzeau, dated Kingston (Jamaica) 1871, *On a method to measure in a direct way the distance between the centers of the Sun and of Venus, during the transits of that planet.* Houzeau, eminent astronomer, arduous topographer, fervent writer and newspaper editor, and at that time owner of a banana plantation, drew attention

to a novel and ingenious way to determine the solar parallax. That his note did not pass unnoticed is proven by another one, published one year later, in which he tries to refute some objections put forward by George Airy (Houzeau 1872). His drive to turn into reality his project was certainly one of the reasons why he accepted, five years later, the offer to become director of the Royal Observatory in Brussels. During the six years of his directorship, "the activity of the Observatory was truly prodigious. Stimulated by the example of its chief, the personnel worked with a veritable enthusiasm" (Lancaster 1887). And it was certainly his feeling of accomplishment, but also the problems with the administration of the Royal Observatory and his aggravating sickness, that led to his resignation soon after the project was carried out.

Two specimen of Houzeau's (1871) heliometer with unequal focal lengths (Fig. 2) were built by Grubb (Dublin) at the initiative of Houzeau and according to plans outlined by Louis Niesten. A description is given in Houzeau (1884), Anonymous (1898), and Van Boxmeer (1996). The instrument has a half-objective of 220 mm diameter and 4.34 m focal length, and a half-objective of 30 mm diameter and 0.14 m focal length, which actually forms part of the eyepiece unit of the telescope (Figs. 3 and 4). The pair of objective lenses was acquired by Quetelet in 1844 with the lens-maker Cauchois in Paris. The eyepiece projects a solar image on a screen (Fig. 5), which was made in 1882 at the Observatory. The projected large solar image has a diameter of 160 mm on the screen, while the diameter of Venus is about 5 millimeters. The short-focus objective produces a solar image a little bit smaller than that of Venus. The relative position of both objectives can be changed by means of a graduated micrometer screw that moves the small lens. This permits to produce a precise coincidence of the small image of the sun and that of Venus (Fig. 6). The difference in micrometer reading between the positions "small Sun centered on crosshairs, being the center of the large Sun" and "small Sun centered on large Venus", properly calibrated, gives a measure of the distance between the centers of both objects during the transit.

The measurements were done in such a way that one observer centered the "large Sun" on the screen by fine motion of the telescope, a second one did the centering of the "small Sun", first on the crosshair and subsequently on the Venus image, and a third one read the micrometer settings and the times (and recorded the observations).

Both the two large and small half-objectives (the large ones secured on fixed brass mounts), a projection screen, at least one tube and major parts of a mounting, and two eyepiece units with microm-



HÉLIOMÈTRE A OBJECTIFS INÉGAUX.

PHOTOTYPIE WILH. OTTO, BRUXELLES.

Figure 2. The heliometer with its projection screen on its parallactic mounting (from Houzeau 1884).

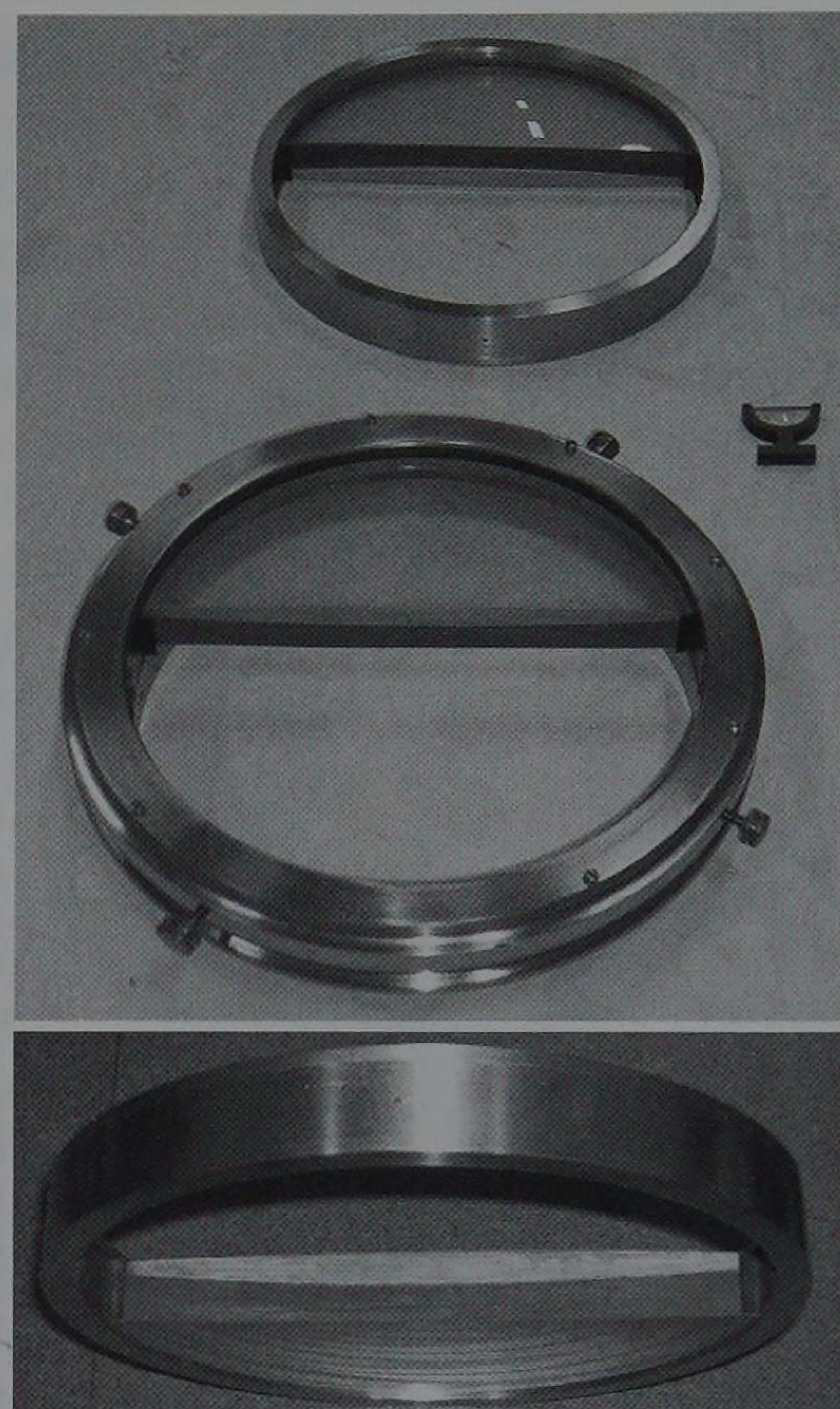


Figure 3. *Top*: two large and one small half-objectives. *Bottom*: large objective in vertical position, edge of lens facing upwards.

eter screws for the small objectives survive at the Royal Observatory of Belgium; the optical items and the screen (with a sketch of a Venus transit as seen with such an instrument) are on display at the Museum of the Royal Observatory.

3. The Belgian Expeditions and the Teams

Two expeditions of the Royal Observatory of Belgium (ROB) were carried out, one to San Antonio, Texas, and one to Santiago de Chile. We give here a brief overview of the expedition members and the equipment, as well as biographic sketches of the expedition members.

- *Albert Lancaster* (1849–1908) reorganized the climatological network of stations in Belgium and in 1898 was appointed scientific

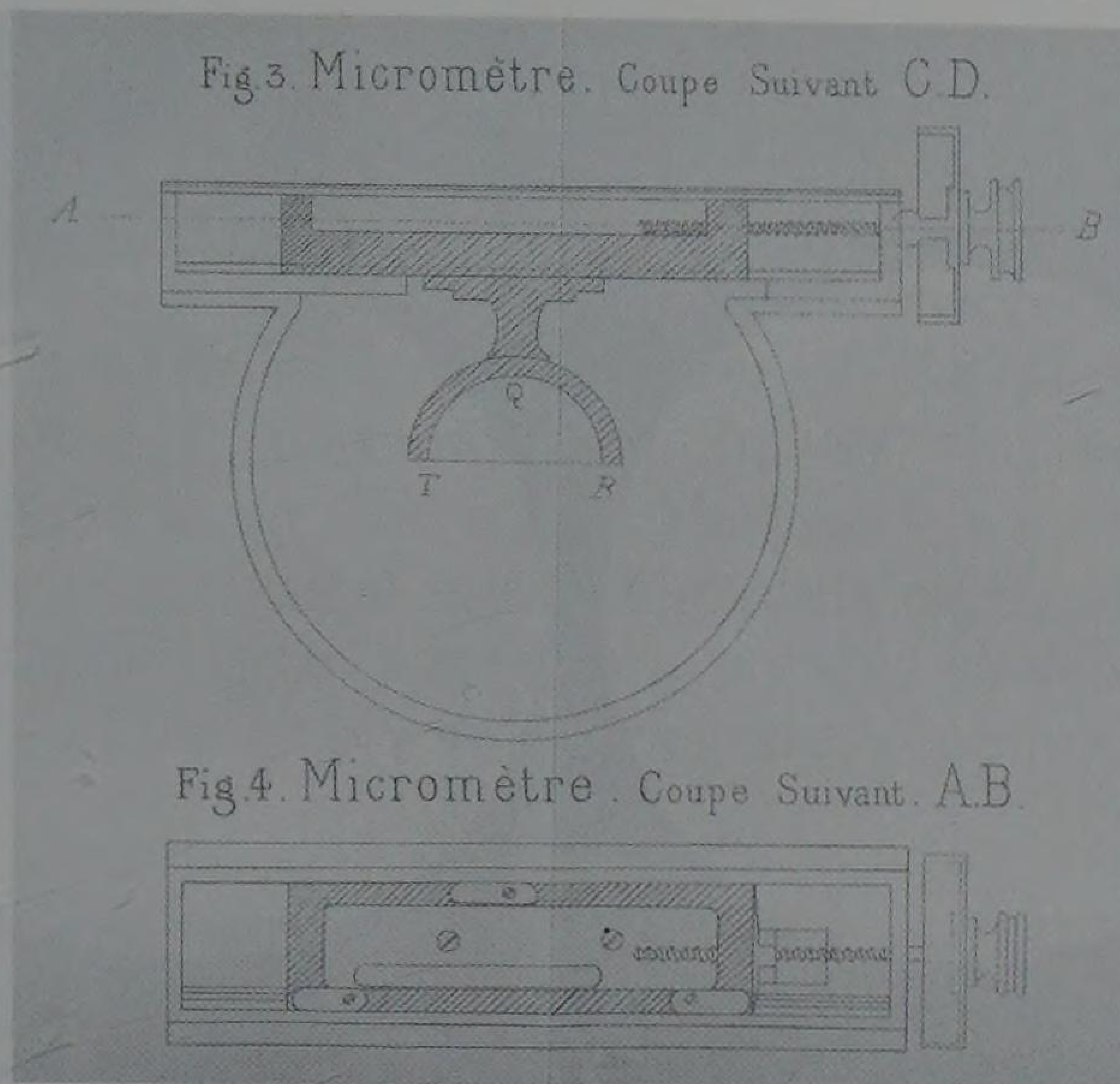


Figure 4. The small half-objective on its micrometer sledge (construction plan by L. Niesten; from Houzeau 1884).

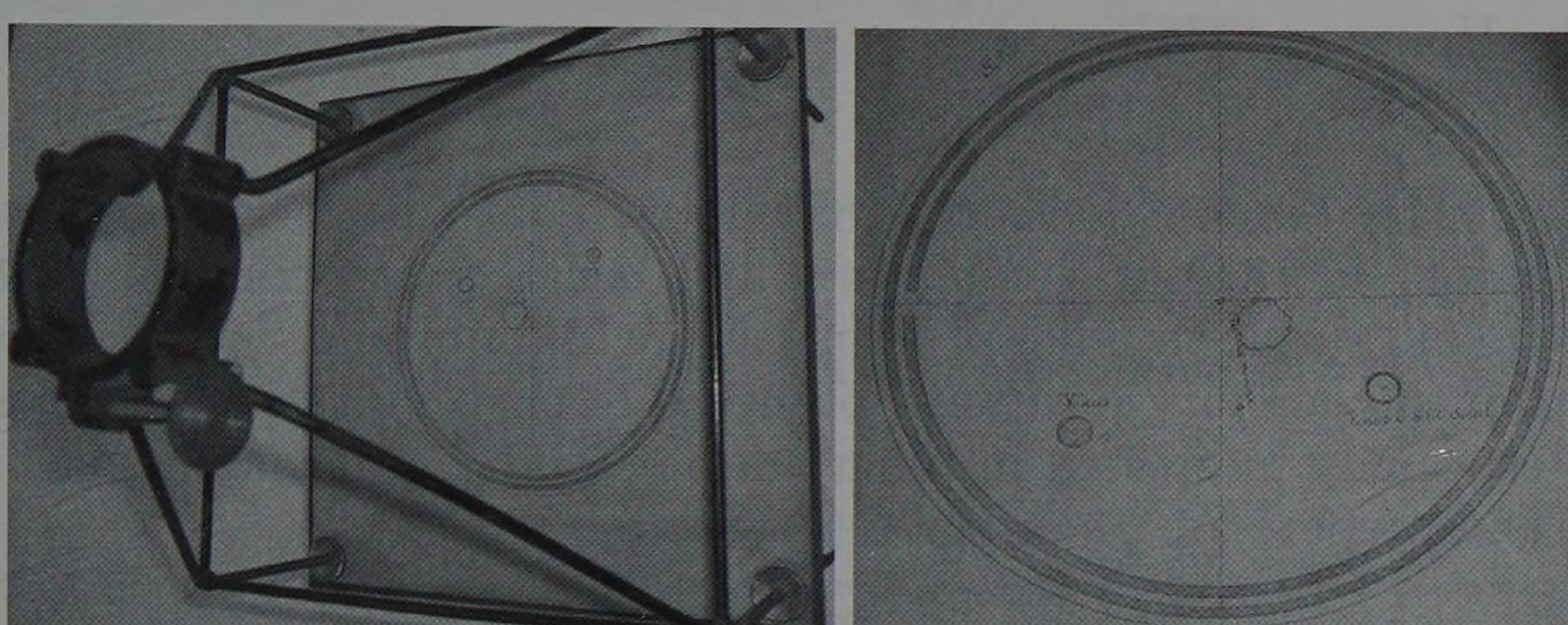


Figure 5. Close-ups of the surviving projection screen surface, showing the centering circles for the large solar image ("Grand Soleil"), the silhouette of the dark "Vénus", and the appearance of the small Sun centered on the dark Venus ("Vénus et petit Soleil"). Furthermore, the smallest distance of the centers of both objects is marked ("distance minima").

director of the meteorological service, a post that he kept till the end of his life. Together with Houzeau, he wrote a "Traité élémentaire de météorologie", and the legendary "Bibliographie générale de l' astronomie" (Mourlon 1908, Anonymous 1980).

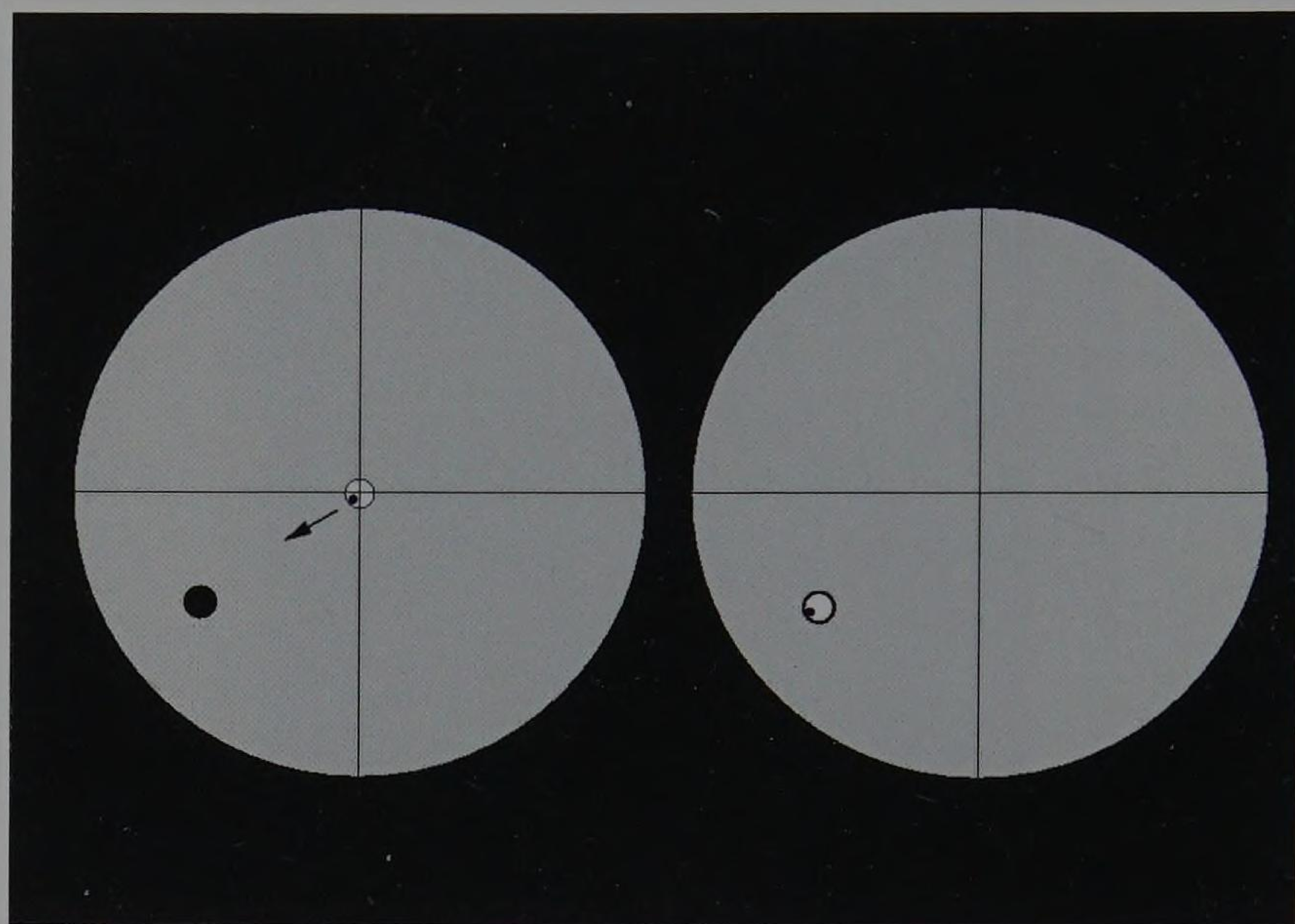


Figure 6. The principle of measurements with the heliometer with unequal focal lengths (adapted from sketches given by Houzeau 1871).

- *Charles-Emile Stuyvaert* (1851–1908) entered the Royal Observatory in 1879 as a voluntary, and became astronomer in 1881. He did surface studies of Venus, Mars, Jupiter and Saturn, determined cometary positions, observed lunar occultations, and was especially interested in lunar surface studies; he made drawings and prepared a moon globe (Stroobant 1909).

- *Louis Niesten* (1844–1920) (Fig. 1) was born in Visé near Liège, and made his first studies in the military academy; he rose to the rank of artillery captain, but left military service in 1877 to work as a scientist. Zegers mentions many papers by Niesten on the physical properties of Jupiter and Mars, on comets, asteroids and double stars, as well as of a Mercury transit. In 1884 he became astronomer and chef of the service of mathematical astronomy. In 1898, he succeeded Charles Lagrange as scientific director of the astronomical service, a post that he kept till 1900[1].

---

[1] These and the following biographical data are taken from Zegers (1883) and supplemented by Anonymous (1932, 1980).

- *Charles Lagrange* (1851–1932) was born in St. Josse-ten-Noode near Brussels, also took first studies in the military academy, became artillery lieuenant in 1874, but moved to the Observatory services in 1878; Zegers also mentions theoretical and observational studies, as well as a history of the physical sciences in Belgium between 1830 and 1880. In 1897, he became director of the astronomical service, a post that he left a year later to dedicate his life to historical research, mainly on the chronology of the biblical prophets. He was also a notable professor at the Ecole Militaire, and wrote several works on the philosophy of sciences.

- *Joseph Niesten*, born in Visé near Liège in 1847, entered military school in 1867, and became lieutenant of artillery in 1870. Since he also took part in astronomical projects in the Royal Observatory, and because of his practical and theoretical knowledge of astronomy, the war ministry agreed that he joined the astronomical expedition led by his brother.

Table 1. Instruments used by the observers for contact observations (during the actual transit, all members were working with the heliometer).

Members	Function	Telescopes
J.C. Houzeau	director, mission leader	Merz refractor 110 mm, 125×
A. Lancaster	meteorologist-inspector	Heliometer with unequal focal lengths
E. Stuyvaert	adjunct astronomer	Fraunhofer refractor 75 mm, 90×
L. Niesten	astronomer, mission leader	Dollond refractor 110 mm, 140×
C. Lagrange	adjunct astronomer	Troughton & Simms refr. 90 mm, 160×
J. Niesten	lieutenant of artillery	Heliometer with unequal focal lengths

Table 2. Geographical location of the Belgian Stations.

Station	longitude	latitude	location
San Antonio, Texas	98°27′45″ W	+29°26′33″	Fort Sam Houston
Santiago de Chile	70°41′45″ W	−3°26′42″	Obs. Nacional

4. The Expedition to San Antonio, Texas

Houzeau departed to the United States on June 30, 1882. Lancaster departed from Antwerp, 22 July, on the steamer *Waesland* (of the Belgian Red Star Line) with the equipment of the expedition; the atlantic crossing to New York took 12 days. He found instructions by Houzeau and the NY Belgian consul how to proceed. The instruments were loaded on August 12 on the steamer *San Marcos*, destination Galveston, and from there they were transported by railroad to San Antonio, where they arrived on August 30 in perfect state.

In Washington, he visited the Naval Observatory and the Signal Office (telegraphy and meteorological observations), and the Smithsonian Institution. Then he traveled by railway through Kansas – Colorado to San Antonio, where he arrived on September 2.

The Belgian observatory was located in the back garden of a rented wooden house "in an isolated situation" (Houzeau 1884) that faced the Staff Post and the Quadrangle of "Government Hill" (its present-day name Fort Sam Houston was only assigned in 1890). Evans & Olson (1990) suspect that the house (which no longer exists) was "probably on the south side of Grayson Street, in the block between the streets now called North Palmetto Avenue and Pierce Street. The telescope piers were approximately 640 feet south and 950 feet west of the clock tower in the Quadrangle."

Houzeau, as an experienced topographer, has also published a list of measurements of buildings and other features of San Antonio in the final report (Houzeau 1884); the copy of a handdrawn map giving a bird's eye view of San Antonio is found in the archive of the Royal Observatory of Belgium.

We owe the most detailed description of the Texas observations to Lancaster (1882):

> San Antonio is the headquarter of the troups which are stationed in Texas, and the barracks are on Government Hill, 7 km NE of the city, at an isolated and elevated location,

> where the view passes a huge horizon and where also the Belgian station was installed [...] The Belgian flag floats in the wind at a small distance of that of the grand American republic. [Lancaster then gives a few details about the city, the inhabitants, and the evening dinners outside on the Plaza de las Armas.]
>
> On the 5th, slight cirrus gave us some fears, but at nightfall there was no trace left. The night from the 5th to the 6th was very good till 5 in the morning, at 5 1/2, rapid clouds showed up and covered the sky in a few moments. All our instruments were ready since the evening, and pointed to the direction where Venus should appear in front of the sun. At 6 1/4 in the morning, M. Houzeau went to the American station to compare the chronometers.
>
> The moment of first contact approaches, the sky is always covered, and remains so till about 9 am; then the clouds appear to be less thick, some hazy brightenings show up here and there, and our hope returns.
>
> Suddenly we see the solar disk through a thin cloud; but another one covers it immediately, and this hope and anguish goes on for 30 minutes. At around 9 1/2, a brighening which is larger than the previous ones permit to point at Venus between the clouds, 12 minutes before the moment of the minimum distance of centers. From that moment on we can make micrometric measurements, with a few interruptions, till the end of the transit. These measures which form the main body of our observations are 124 in number, and some refer to the time when the planet was closest to the solar center. [...] At 1h 14m and 1h 34m we observed the two last contacts on a sky which was almost free from clouds. And everything was finished!

But in his extensive obituary, Lancaster is much more detailed on Houzeau's state of mind in the morning of the transit when the sky was overcast (Lancaster 1887): "Houzeau did not say anything, but his face became very pale; not a muscle of his face moved; we understood that he was undergoing a deep inner trouble. He returned to our little house and laid down on the floor, as he liked to do it, and said to us that we should notify him if some change in the sky conditions should arise."

And there is another line in Lancaster's (1887) obituary that merits citation with respect to the Texas expedition since nothing is found in the official reports:

> "Soon after his [Houzeau's] return to Belgium [in 1876], he re-married with his sister-in-law, the widow B. Discry, who accompanied him on his trips to Jamaica in 1878, and to Texas in 1882, and who cared for him, from the first days of his sickness to which he would finally succumb, with an unlimited devotion."

A State of Texas historical marker will be established at the Belgian Transit of Venus Observation Site at the place where Houzeau observed the transit, not far from the marker honoring the observation of the Transit of Venus by the American expedition to San Antonio in 1882.

5. The Expedition to Santiago de Chile

Luis Ladisláo Zegers, a physicist at the Universidad de Chile, wrote a "*noticia histórica*" on the observations carried out in Santiago and its vicinities. He cites a lot of correspondence and newspaper clippings, talked with the Belgian and U.S-American scientists, and actively took part as an assistant of the French transit expedition. Zegers is best known today because of his use of Röntgen's newly discovered X-rays for medical purposes in Chile only a few months after their first application in 1895 (Zegers and Salazar 1896). Let us briefly mention that Zegers' (1883) book does not inform us about the activity of the Chilean National Observatory on 1882 December 6, since this was obviously restricted to the "authorized word of its director", José Ignacio Vergara. Instead, Zegers quotes from Vergara's newspaper articles of the forthcoming event, gives a long history of the National Observatory, deplores its present state of decline, and then very briefly lists contact timings derived by Chilean personnel at the observatory ("we owe these data to the kindness of the director of the National Observatory"). And this remained, according to our knowledge, the only printed result of the Venus transit observed by the Chilean National Observatory staff. For a detailed history of the Chilean National Observatory, the reader is referred to Keenan et al. (1985).

The Belgian project started with an exchange of letters between Houzeau and the director of the Chilean National Observatory, José Vergara:

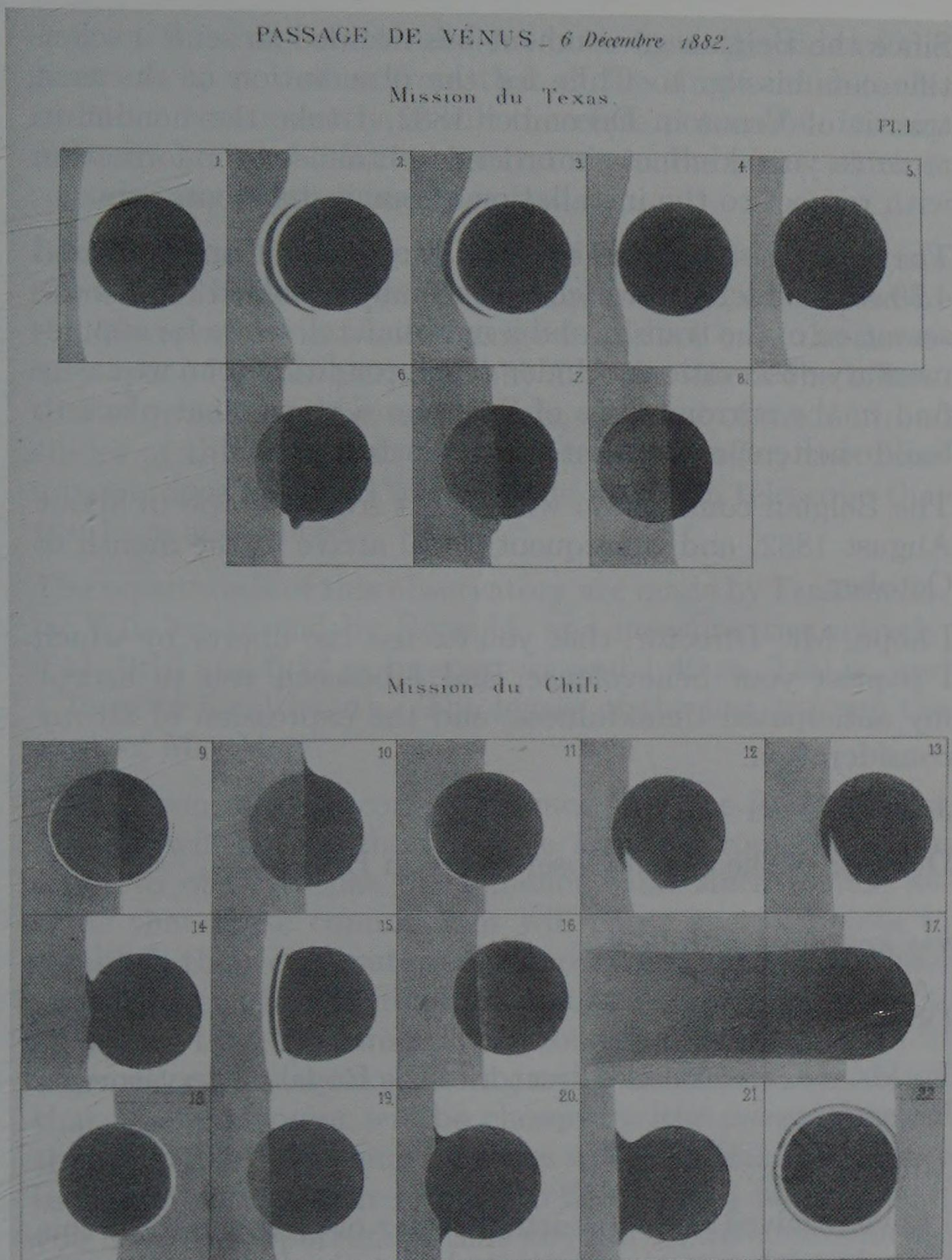


Figure 7. Visual black drop observations, recorded by E. Stuyvaert in San Antonio and by C. Lagrange in Santiago de Chile (from Houzeau 1884).

Brussels, October 16, 1881

To the Director of Santiago Observatory.

Mr. Director:

Since the Belgian government has decided to send a scientific commission to Chile for the observation of the next transit of Venus in December 1882, I take the honour to recur to your kindness in order to obtain some information with respect to the installation of our instruments.

They comprise a large equatorial of 0.18 m aperture and 4.30 m focal length, which is especially designed for the observation of the transit, and a meridian telescope for supplementary observations. Under which conditions can we easily find in the surroundings of Santiago a convenient place to build shelters, and to put up the instruments?

The Belgian commission will depart from Europe in about August 1882, and consequently will arrive in the month of October.

I hope, Mr. Director, that you excuse the liberty by which I request your benevolence, and I beseech you to accept my anticipated thankfulness, and the expression of all my consideration.

J.C. Houzeau

Director of the Royal Observatory in Brussels.

This was answered as follows:

December 24, 1881

To Mr. J.C. Houzeau, Director of the Royal Observatory in Brussels.

Mr. Director:

I have received your important letter of October 16 of this year, in wich you communicated that the Belgian Government has decided to send to Chile a scientific commission with the aim to observe the next transit of Venus, and in which you ask me about the possibility to find a convenient place in the surroundings of Santiago for the instruments that this commission will bring along.

In answering with true joy to your mentioned letter, it is especially pleasant, Mr. Director, to be able to signal to you that the said commission will find in this capital all the facilities which it can expect for the performance of its

duty in this important mission, both from the side of the government as well as from that of the single inhabitants, and that consequently it will therefore not encounter any difficulty to establish its observatory in the place which it considers most advantageous.

Being authorized by the Minister of Public Education, I can immediately offer you in the same place that is occupied by the Observatory in whose charge I am, not only the necessary space for this purpose, but also the use of the offices, that of one of the three equatorials, and that of the meridian circles of this institute. If you accept this offer, the Commission does not need to bring the meridian telescope that you have announced.

The equatorials of this observatory are made by Fraunhofer, by Würdeman and by Repsold, and measure, respectively, 0.11, 0.16 and 0.23 m in aperture and 1.40 m, 2.60 m, and 4.25 m in focal length. The lenses of the last one are the work of Mr. Merz.

I have seen in some correspondence that the Belgian commission will not be the only one arriving from Europe in order to observe that phenomenon, and since I must assume that these commissions will chose special points to establish their observatories, not only the purpose of these should be considered, but also, in order to prevent the possible case that the atmospheric condition prevents work in a given location, I take the liberty to announce in addition that whatever point will be chosen by [the commission] of that Republic, the same facilities will be found that I have indicated to you with respect to Santiago. I hope that, if you have the opportunity, that you can use to communicate the previous facts to the abovementioned commissions.

With the sentiments of my distinguished consideration, I take the honour to offer myself to you, Mr. Director, as your zealous and true servant.

José Ignacio Vergara.

Indeed, other researchers from abroad came to Chile: The French would establish their observing station at Cerro Negro, an area near the town of San Bernardino, a few kilometers south of Santiago, the

US Americans in the parque O'Higgins in Santiago, the Germans and Brasilians in Punta Arenas, the (then) only major settlement in the southernmost 12th region of Chile. Details are found in Duerbeck (2004a,b).

The Chilean party consisted of Louis Niesten, astronomer at the Royal Observatory of Brussels (chief of mission), Charles Lagrange, adjunct astronomer at the same institution, and Louis' brother Joseph Niesten, an artillery lieutenant on leave from the War Ministry. Details are given in Houzeau and Niesten (1883) and Houzeau (1884). A 45-day trip on the steamer *Denderah* (of the German *Kosmos* line) brought them from Antwerp to Valparaiso. After a railway trip of five hours, they arrived in Santiago on 1882 September 2.

A few days after arrival, tbe Belgian commission began to install its instruments in an annex of the National Observatory "somewhat to the south and facing the large tower that contains the new equatorial" (Zegers 1883:173). The director of the Quinta Normal, René F. Le-Feuve, offered in the name of the Sociedad Nacional de Agricultura living quarters near the observatory grounds to the Belgian astronomers.

December 6, the day of the transit, was perfectly clear: "Since dawn, a clear sky – only a few clouds above the snowy peaks of the Andes – promised a wonderful day" wrote Niesten in his diary (Houzeau 1884). Indeed, 606 measurements of the position of Venus were taken with Houzeau's heliometer, and additional observations were made with refractors. The latter ones show the phenomenon that had already plagued the 18th century observers: the black spot that appears at second and third contacts (Fig. 7), which makes accurate timings of the moments of internal contacts virtually impossible.

"The measurements were carried out with the outmost easiness, and with a great precision" wrote Louis Niesten to Zegers (1883:177). "During the time of the transit, the Belgian commission was able to determine 606 positions of Venus on the solar disk." And Zegers adds: "When the heliometric results of the two Belgian stations, that of Texas and that of Chile, will be combined, the Belgian astronomers will without doubt achieve to determine the value of the solar parallax with a completely novel method which will establish itself with all signs to be an excellent one."

After finishing the observations, the party went by railway to Santa-Rosa, crossed the Cordillera on muleback, and again by train to Rosario, where a steamer brought them to Buenos-Aires. After short stays in Montevideo, Rio de Janeiro and Petropolis, they returned

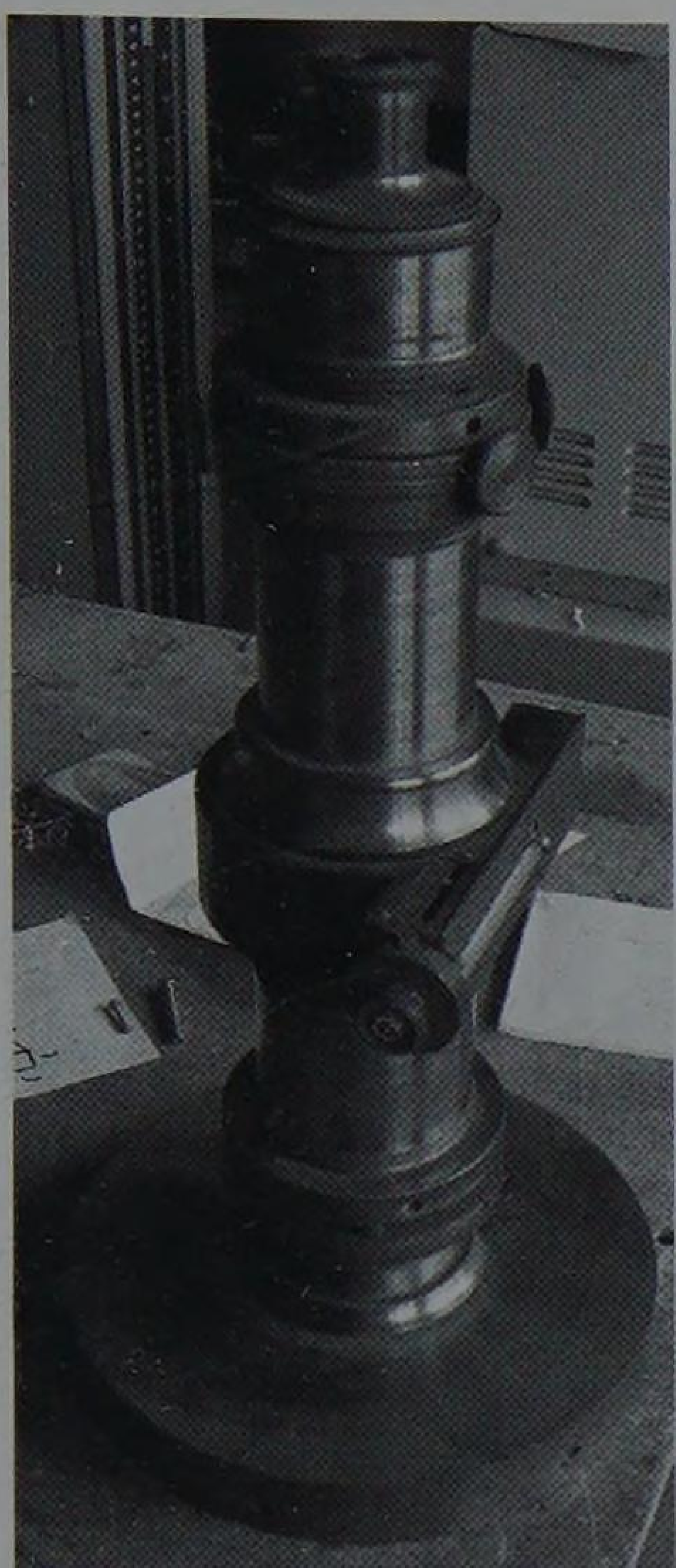


Figure 8. Adaptor (for supporting the projection screen) with micrometer.

with the steamer *Sénégal* of the Messageries Maritimes via France to Belgium, happily finishing "the first scientific expedition organized by Belgium" (Houzeau and Niesten 1883).

6. Results

Two years after the transit, Houzeau (1884) published the report of the campaign. A lot of – partly unforeseen – corrections had to be applied to the measurements: for example, the crosshair of the heliometer used in Santiago had been damaged on the trip, and had to be replaced by one which was not properly adjusted, thus corrections for eccentricity had to be carried out. The small Sun and Venus had of course different zenith distances, thus differential refraction corrections had to be applied, which amounted to different values in both locations, and these values directly influenced the resulting parallax value. Houzeau, as all other investigators, used a preliminary model of the Sun-Venus-Earth system, with an assumed solar parallax of $8''\!.86$, and from the observations he worked out the corrections to the assumed values. Unfortunately, his observations carried him even further from the true value; his final result was $8''\!.911 \pm 0''\!.084$ for the solar parallax. While the parallax value can be taken as one based on a new

and independent method, and thus something that can be regarded as a true achievement, Houzeau was less happy about the unexpectedly large error, which he mainly blamed on the poor sky conditions in San Antonio.

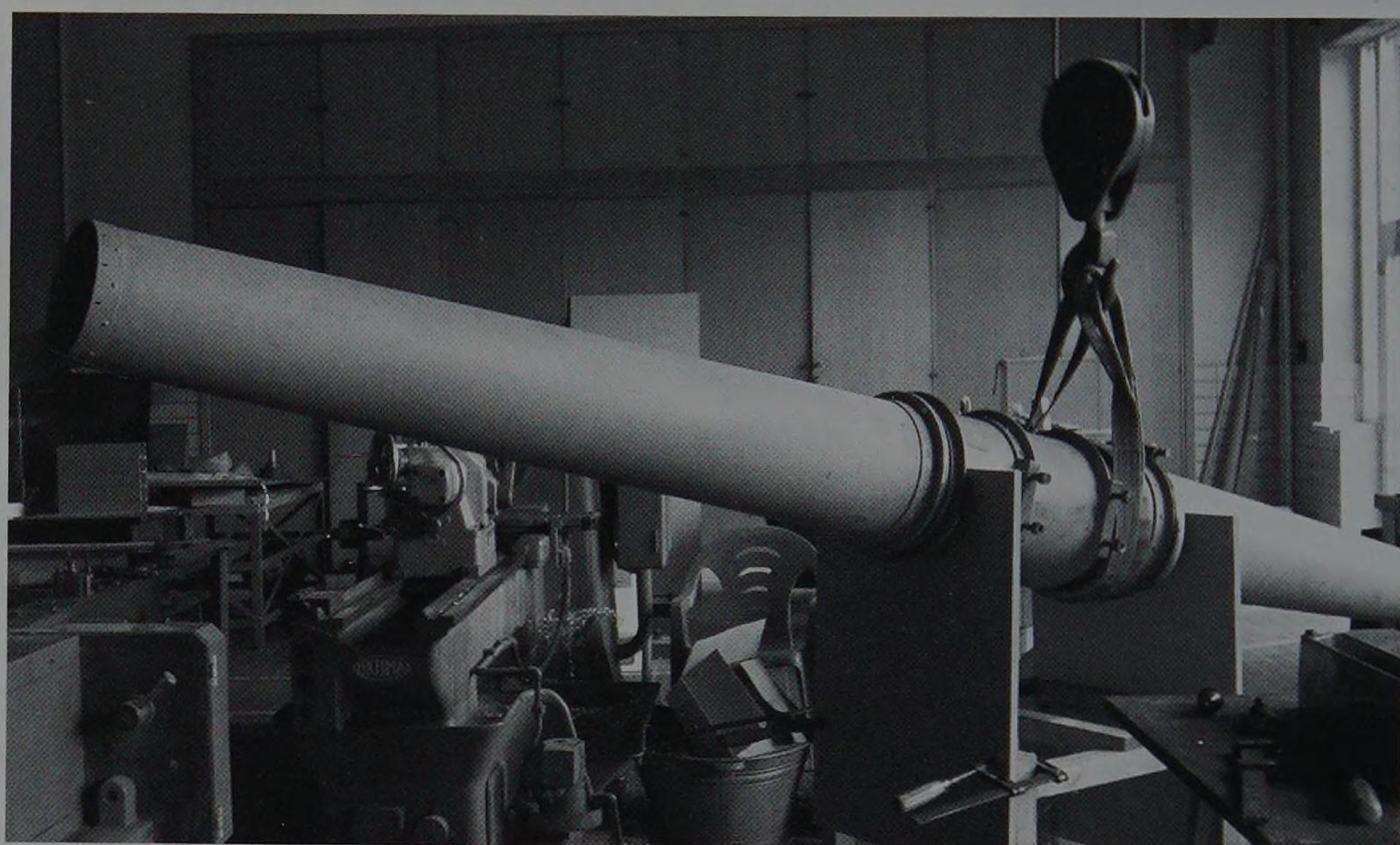


Figure 9. Heliometer tube in the ROB Workshop.

7. The Whereabouts of Houzeau's Instruments

Figures 5 and 9 show the adaptor and the heliometer tube in the Workshop of the Royal Observatory of Belgium. Projection screen and lenses (from the Royal Observatory of Belgium Museum) were already shown in Figs. 3–6.

At the 2000 General Assembly of the IAU in Manchester, a Resolution was adopted recommending that the sites of previous transit of Venus expeditions be inventoried, marked and preserved, as well as instrumentation and documents associated with these expeditions. The safeguarding of these Belgian historical instruments, no doubt is a valuable contribution to the archival efforts encouraged by the International Astronomical Union.

On the occasion of the Venus transit of June 8, 2004, the heliometer tube and the optics were restored, cleaned and put on a primitive mounting. On the day of the transit, the heliometer was installed on

Figure 10. Assembled heliometer tube mounted on trailer for the June 8, 2004 Venus transit (ROB grounds).

a trailer. Personnel and visitors of the Royal Observatory, including many school children, had on the day of the transit the opportunity to observe the (projected) Sun and Venus with the same instrument as 122 years ago. The quality of the images was very bad, maybe because of the ageing of the instrument, maybe because the intrinsic optical quality was not that good. In the latter case, it is not surprising that no very precise measurements could be done with this instrument. Nowadays the heliometer is still on exhibit in the hallway of the Royal Observatory.

8. Conclusion

In the history of astronomy, the 19$^{\text{th}}$ century transits do not occupy the same rank of importance as those of the 18$^{\text{th}}$. While in the sequel of the 18$^{\text{th}}$ century transits, there was no immediate way to replace the method by another one, the refinement of other, concurring methods

in the second half of the 19^{th} century – even when the "transit season" was underway – led to a critical evaluation of different approaches to determine the astronomical unit, which is perhaps best exemplified in Newcomb's varying views how to handle the problem of solar parallax. And when a suitable minor planet – Eros – was discovered, which provided all the advantages, and none of the disadvantages of Venus, the method of Venus transits fell into oblivion. There was no 20^{th} century Encke who tried to homogenize the 19^{th} century results. But the importance of solar parallax, which was recognized to be just one mosaic stone in the system of astronomical constants, was clearly recognized by some of the leaders in the field, like Harkness (1891) and Newcomb (1895), who sat down to determine consistently such a system, based on the foundations that Houzeau had laid by compiling the first – and perhaps most extensive and erudite – compilation of "astronomical quantities" in one of his *opera magna*, the "Vade-Mecum de l'Astronome" (Houzeau 1882). So we recognize in Houzeau a unique person, who was both a compiler and a researcher, a republican and a "Royal astronomer", a Belgian and a cosmopolitan.

Acknowledgements

Many colleagues have supported our research on Venus transit expeditions; here we want to express our particular gratitude to Mr. Pierre Alexandre, archivist at the Royal Observatory of Belgium, the people at the technical workshop at the Royal Observatory of Belgium, Prof. Hector Alvarez, Departamento de Astronomia, Universidad de Chile, Santiago, Mrs. Maria Eugenia Gomez, Librarian at the European Southern Observatory, Santiago, and Mr. Hans-Emil Schuster, Hamburg.

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ASTRONOMICAL HERITAGES: ASTRONOMICAL ARCHIVES AND HISTORIC TRANSITS OF VENUS

A selection of papers prepared by Working Groups of Commission 41 of the International Astronomical Union

Edited by C. STERKEN and H.W. DUERBECK

This book contains a selection of presentations and research papers emanating from meetings of the Astronomical Archives and Transits of Venus Working Groups of Commission 41, and from presentations at the last three IAU General Assemblies. Some additional reports related to the topic of this book have also been added. The first part of the book deals with archives, the second part with facts related to historical transits of Venus.
This compilation deals with many wonderful and even rare sources of information, such as official documents and reports, private letters, astronomical instruments and telescopes, national inventories, photographic plates, etc. A lot of documentation described in this book is available only on national level, and the combination of this material in one single volume looks like a cross-cultural study dealing with art and science, and almost can serve as a travel guide in time and space.

Christiaan Sterken is Research Director at the Belgian Fund for Scientific Research (FWO) and works at the Department of Physics at the Vrije Universiteit Brussel, Belgium. His principal field of research is photometry of variable stars, a discipline in [illegible] se is made of historical archives and ancient star catalog[illegible] observational astronomy and the history of physics at the U[illegible]

Hilmar W. Duerbeck is honorary professor at the University of Münster, Germany, and a research associate at the Vrije Universiteit Brussel, Belgium. His research interest is focussed on observational studies of binary stars, cataclysmic variables, and late stages of stellar evolution. He is interested in the history of cosmology and the history of astronomy in Germany. He serves as one of the secretaries of the History of Astronomy Working Group in the Astronomische Gesellschaft, and is a member of the Transits of Venus Working Group of Commission 41 of the International Astronomical Union.

ISBN 9080553867